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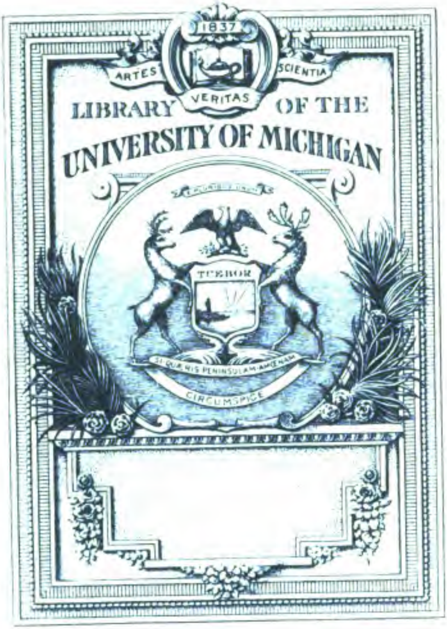
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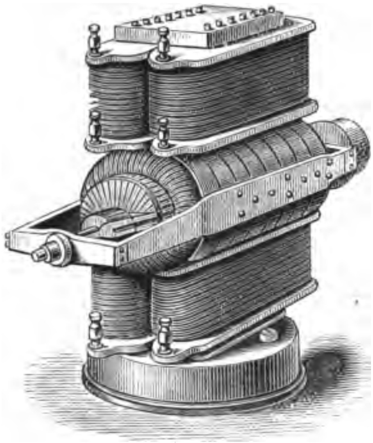
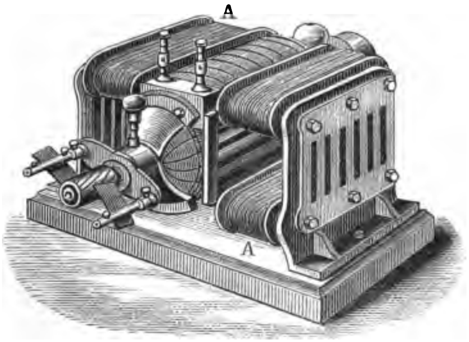


MAXIM'S DYNAMO-ELECTRIC MACHINE.



WESTON'S NEW DYNAMO-ELECTRIC MACHINE.

[*See p.* 88.]

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ELECTRO-TYPING

A PRACTICAL MANUAL

FORMING
A NEW AND SYSTEMATIC GUIDE TO THE REPRODUCTION
AND MULTIPLICATION OF PRINTING SURFACES
AND WORKS OF ART BY THE ELECTRO-
DEPOSITION OF METALS

BY

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ITS PRODUCTION AND USE," &c.

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PREFACE.

THE author's endeavour to treat, in an easily apprehended style, upon another branch of the Electro-metallurgic art ("Electro-Plating"), has received so much encouragement that he has been induced to offer the present handbook as a companion volume, in the belief that it will meet a want of considerable extent.

The distinct art of electro-typing has, within the last few years, advanced with such wonderful rapidity that it is now practised as an impórtant auxiliary in industries of the most varied description. The particular methods employed in the processes ten years ago may now be considered in great part obsolete, improved systems having superseded them. This small treatise is therefore intended to serve as a guide, not only to beginners in the art, but to those who still practise the old and imperfect methods of electro-typing; it aims also at preparing the way for a thorough scientific study of the art, if such be considered necessary for its successful prosecution.

The introduction of cheaper electrical generators, in the form of dynamo-electric machines, driven by steam-power, has brought about many of the changes above alluded to. The Americans have exhibited great enterprise of late years in cheapening every detail of the process, which English electrotypers have not been slow to appreciate, adding to both speed of working and excellence of the products; but on the Continent, especially in Germany, the art is as yet in a backward state.

In the following pages special prominence has been given to the production of printing electrotypes, and to the reproduction of art work. An endeavour has been made to grasp the fundamental principles of the art; an earnest attempt has been made to induce the reader to take some interest in the scientific basis of the processes, by giving practical examples of the use he can make of the oft-misunderstood and generally confusing laws of electro-chemical science.

The first chapter of the book is in great part occupied by explanations of the leading electrical laws, and their relation to the chemical compounds to be subjected to electrolysis. An endeavour has been made to reduce the terms, "current of electricity," "amount of deposit," and so forth, to some real and easily apprehended meaning, in order that the reader may be able to attach practical significance to the current he is using, and reconcile its amount with the weight of copper he can obtain. Some little acquaintance with chemistry on the reader's part has been assumed, but of electricity he is supposed to know little or nothing; he will, however, derive great benefit from a careful perusal of the electrical laws in some good text-book.

The second and following chapters of the work are devoted to instructions to the operator, with a special bearing upon ordinary requirements. The use of the dynamo-electric machine is explained at length. The description of apparatus employed by the electrotyper has received careful attention; the materials now usually found best suited to the different sections of the art are described; the preparation of work for the depositing process is treated at considerable length, and the process itself has been carefully detailed in Chapter VIII. The work is thus arranged in ten chapters, one division being devoted to each important section of the art: the divisional paragraphs, when they open a new portion of the subject, are furnished with italicised headings.

LONDON, 1881.

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ELECTRO-TYPING.

CHAPTER I.

Introduction to the Art.

THE electro-depositor's art is so widely disseminated over numerous modern industries, that to give a concise and comprehensive definition of the compound term electro-typing is rather difficult. Its general significance, however, may be understood to imply the production of *metallic copies and duplicates of objects by means of electricity*.

Thus, an electrotype of a wood engraving consists of a metallic duplicate, accurate in every detail. It possesses the additional advantage of being better adapted to printing purposes than the original.

An electrotype of a plaster bust, or a bird, or a fish, forms an accurate metallic reproduction of the original, rigid, and indeed everlasting.

In some important respects the products of this fascinating and beautiful art resemble the results of photography; every line, excellent feature and defect, is reproduced with a faithfulness almost surpassing belief. From the nearly invisible lines of the finest steel engraving to the boldest contour of a statue, the electrotype is throughout an exact and unmistakable reproduction.

Copper is the metal almost universally employed in the production of electrotypes. It is cheap, ductile, strong, and flexible, and is admirably adapted for printing purposes in many cases where various other metals and wood are inadmissible. It also presents an agreeable and attractive appearance in art reproductions. Electrotyped printing surfaces may be, and frequently are, so protected from the effects of wear, by means of a thin and hard facing of iron, brass, or nickel, that they may be made to yield as many as from ten to twenty thousand impressions. The "steel face," or its remains, may, moreover, be dissolved off, and the process repeated without loss of sharpness or injury to the original; in this manner the printing electrotype may be made infinitely more useful than the prototype itself.

Engraved steel plates are not now, owing to their great value, used generally in printing; electrotypes, steel-faced, are taken of them and employed in the printing process. Wood blocks of value are similarly treated. Set-up type is frequently in Europe, and almost universally in America, copied in electrotype, instead of by means of stereotyping, the old casting process. Any number of copies of one object or plate, either from the original or from an electrotype, can be obtained. Bank-notes, postage stamps, bill-heads, illustrated newspapers, playing cards, grocers' wrapping papers, maps, and numerous other kinds of printing work are executed from electrotype plates.

In the domain of art the applications of the electrotype are no less widespread. It is employed to produce copies of the smallest medals, casts, and coins; its application to the production of gigantic statues and ornaments may be inspected in almost every public recreation ground; and in great perfection on the celebrated Albert Memorial, in Hyde Park. It is almost impossible, and its accomplishment would prove of little use, to detail the numberless applications of the art; they are legion, and may be said to be enormously augmented in numbers yearly.

Having thus obtained an outline conception of the field in which the electro-typer's art is utilised, it will prove instructive to briefly examine the main manipulatory features and forces necessarily employed in its general practice. It will be well to premise, however, that electrotyping and electro-plating are very closely related to each other; indeed, one is often classed with the other. They are both deposits of metals laid in position by means of electricity, but except in this main particular their application lies in totally different fields. To electro-plate is to disguise with an *adherent* thin *coating* of metal, which then serves as an ornamental covering to the object treated. To electrotype, on the other hand, is to produce a *separate* and *distinct* object, with an existence of its own. The following 26 pages are exclusively devoted to a comprehensive discussion of the chief conditions under which the electro-depositor's art is practised. This section of the work is intended to serve as an introductory lesson, in which the fundamental laws of the science, as applicable specially to the production of electrotypes, are laid down and defined. It will well repay the student to give it careful attention, with reference, where necessary, to works on electricity; no difficulty will afterwards be encountered, because the remaining chapters refer chiefly to the apparatus and manipulation by means of which these primary principles are utilised.

A condensed outline of the Art.—This must be accepted merely as an outline sketch, to assist the reader to a more intelligent understanding of the principles laid down further on. Let us, for example, select an engraved block from which an electrotype is required. The block is first rubbed gently all over its surface with finely powdered plumbago, which gives a polish and prevents "seizing" in the moulding process; and it is afterwards blown upon with the breath to free it from dust. A frame of sufficient size is now filled up level with a hot melted mixture of the following ingredients:—Bees'-wax, Venice turpentine, and blacklead. This is to form the mould, which is placed directly over the wood block on the level table of a press, when both are forced together with considerable pressure. A little care will now enable the mould and block to be separated. The mould contains a perfect copy of the block reversed. The next process has for its object the provision of a conducting surface for the mould, so that it may conduct the current of electricity sufficiently well to allow of deposition being proceeded with. This is done by carefully brushing plumbago over its surface with soft brushes until a uniform polished film is produced; this conducting surface is so spread as to allow of the copper being deposited all over the mould. Those portions which should not receive a deposit are "blocked out" by varnish. The mould is now hung in a vessel containing an acidulated solution of sulphate of copper. A wire from the negative pole of a galvanic battery is attached to it, while the positive pole is connected with a copper plate, termed the anode.

Deposition of copper upon the mould immediately commences, beginning at the edges and advancing towards the centre. When a sufficient thickness of "shell" is obtained, which may take a few days to accomplish, the mould is removed, heated, and separated from the "shell." The surface of this electro-deposit is found to be in every respect a duplicate of the original block, but it is yet too weak for printing purposes. It is tinned and backed with a layer of an alloy of lead and tin, squared, planed flat, and finally mounted upon a wooden block, type high. It may now be printed from.

Such is the mere routine of the process, as applicable to common wood blocks, which would not prove of material assistance to the reader were he to try the experiment and ignore the *details* upon which the success of the operation mainly depends.

To gain a mastery over the principles of the art, the reader must devote his earnest attention to obtain a correct understanding of the action electricity exhibits in its operation; he should also be acquainted with the best methods by which electricity may be obtained; and must particularly be familiar with the use of currents and the manipulation of galvanic apparatus. The different processes of moulding and preparing he will find comparatively easy, which may also be said of the final preparatory or finishing process. Each important section of the entire process will be found under the different heads, as complete as possible in itself, the more important being discussed first. A slight knowledge of chemistry on the part of the reader will prove of much assistance.

Nomenclature of the Art.—The fundamental principle of electro-deposition may be laid down as follows:—When a current of electricity passes through a solution, as of cupric sulphate, it produces a *chemical change;* the solution is *decomposed,* and the copper *set free.* This will be more fully explained hereafter; at present we are concerned with the terms employed to indicate the nature of the conditions necessary in electro-chemical decomposition. The nomenclature Faraday employed is as follows:—*Electrolysis* (from *elektron*, and *lysis*, a disengaging) is used to designate that branch of electrical science which treats of the laws of electro-chemical decomposition; it includes, of course, the science of electro-metallurgy. A substance capable of being decomposed by a current of electricity is called an *Electrolyte* (that which is *unbound* by electricity). The poles, or wires and plates, by which the current enters and leaves the solution are called *Electrodes* (from *hodos*, a way). The positive pole (+), or that by which the current *enters* the solution, is termed the *Anode* (*ana*, up, and *hodos*, a way). The negative pole (—), or that by which the current *leaves* the solution, is called the *Cathode* (*kata*, down, and *hodos*, a way). The elements of the solution (electrolyte) *set free* by the current are termed *Ions* (from *ion*, going). Those of the elements which appear at the anode are called *Anions*, and those set free at the cathode are called *Cations*. The word *electrolyse* signifies to decompose by means of a current of electricity.

The Electric Circuit.—Apart from any knowledge of the battery by which the electric current is produced, it should be clearly established in the student's mind that the current must, from its nature, always move in a circuit; this signifies that no electricity can pass through a wire or other conductor which does not offer a *complete* and *unbroken* path. By some the word circuit is taken to signify that electricity which leaves a battery must always have a path provided for its return to the battery. The fact is, that no electrical effects can be obtained in a circuit which is incomplete.

Conductors and Insulators.—The properties of all classes of conductors and insulators cannot be discussed here, so that we may select those employed in the art of electro-typing for special treatment. All metals are conductors of electricity. Silver offers least resistance to the passage of electricity, and is, therefore, the best conductor. Copper is the next best conductor, and is universally employed for leading wires from the battery to the depositing vessel. Most solutions and acids are conductors, but offer *considerable* resistance to the current. Acidulated water conducts better than pure water. Dry wood, glass, porcelain, gutta-percha, and, indeed, all such non-metallic substances, offer such *high resistance* to the current that none of it will pass; these substances are therefore termed *insulators*. The resistance of a conductor to the current varies directly as its length; hence, six feet of a particular wire will offer twice the resistance given by three feet. The unit of resistance (by which it is measured) may be roughly taken as about equal to six feet of No. 36 Birmingham wire gauge—pure copper wire—and is called the *Ohm*, from Ohm, the German physicist. It is further spoken of in the section devoted to Measurement.

Current of Electricity.—This means the amount or quantity of electricity actually supposed to be passing in a circuit. It implies, in fact, the working power of the electric influence, or its power to deposit a given amount of copper in a given time. A *weak* current may deposit copper at the rate of five grains per hour only. A *strong* current may deposit as many ounces in the same time. The unit of current or quantity is termed the *Farad* or *Weber* per second. It will deposit in a circuit of one ohm about seventeen grains of copper per hour. It is also known as a "Veber."

Electro-motive Force.—The electro-motive force of a current means that power by virtue of which it can surmount resistance. A current of *low* electro-motive force may be entirely stopped or absorbed by a moderate resistance. A current of *high* electro-motive force can overcome high resistance, or accomplish work in such a circuit. The full meaning of the term will be better understood a little further on, but it should be stated here that the extent of the electro-motive force or tension of a current depends upon the chemical affinity between the plates and solutions of the battery, and also upon the difference between the elements of the battery. The electro-motive force depends to a great extent upon the electrical relationship existing between the plates. Tables of the electro-chemical series are to be found in most text-books, but they generally ignore the fact that, except in dilute acid, the relationships are apt to be reversed. The following list, including the common metals likely to be used in voltaic cells, exhibits the most electro-positive elements first, and the most electro-negative last. Thus, to obtain the most powerful electro-motive force the first and last elements should be combined in the cell. The further they are apart in the list the higher the electro-motive force. The unit of electro-motive force is called a *Volt*.

Electro-Positive +.
Potassium
Sodium
Magnesium
Zinc
Iron
Aluminium
Lead
Tin
Bismuth
Copper
Silver
Mercury
Platinum
Gold
Hydrogen
Antimony
Carbon
Phosphorus
Iodine
Chlorine
Nitrogen
Sulphur
Oxygen
Electro-Negative —.

Battery.—The word battery here signifies that arrangement which in a circuit gives rise to a current. It is the generator of electricity, and is variously styled galvanic and voltaic battery. It may be assumed for the present to be the only generator used; its various forms are fully described in Chap. III.

When a pair of plates (of copper and zinc), not touching one another, are plunged in acidulated water, bubbles of gas arise from the naked surface of the zinc plate. When, however, the plates are connected together by a wire, the numerous bubbles of hydrogen are found to arise from the copper plate, and this goes on until the wire is separated from one of the plates, or the *circuit* is otherwise broken. A *current of electricity* circulates, in fact, throughout the series. While the action lasts the zinc plate is being slowly dissolved, but the copper plate remains unaffected.

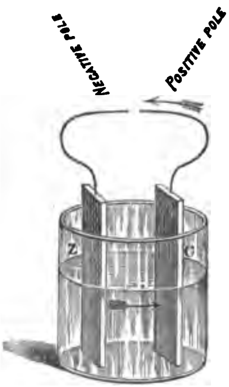


Fig. 1.
Simple Voltaic Generator.

The current is assumed to be set free at the surface of the zinc plate; it moves through the liquid towards the copper plate, and in doing so sets the hydrogen gas free at that plate. The oxygen combines with the zinc and forms sulphate of zinc. The course of the current is assumed to be — starting from the zinc plate, it passes through the liquid to the copper plate, and from its extremity by the wire to the zinc plate again (Fig. 1.) If the wire be cut the current ceases to flow. The zinc plate, being the active element, is termed the *positive* plate or element of the cell. The copper plate, being passive, is termed the *negative* element. The end of the plate at which the current *leaves* the cell is called the *positive pole*, while the end of the plate by which it *enters* is termed the *negative pole*. Thus the extremity of the copper plate forms the positive *pole*, while the zinc forms the negative one. Of course these terms apply equally to any wires attached to the plates. The end of the wire from the copper or negative plate is always known as the positive pole, and *vice versâ*.

These are the fundamental principles of a simple galvanic cell; their full significance must be sought in text-books of electricity devoted mainly to the subject. Enough is given here to enable the reader to understand and act upon that which follows.

The strength of current given by a zinc-copper cell is from various causes low. It is strong at first, but the rapid covering of the copper plate by bubbles of hydrogen and other causes soon brings its force down to a mere fraction of the first rush. Various other generators are in practical use, which yield a constant and powerful current. These will be found described under the heading "Source of Electricity." One cell is a rather weak arrangement. Two or more cells may be so joined together as to act in concert. When we have more than one cell the arrangement is called a battery, but the word battery is generally used throughout this treatise, although one cell cannot properly be so termed.

The way in which cells may be joined together to form a battery will be found described under "Source of Electricity," but we may briefly examine the effect of connecting two cells together in this place. When the zinc of one cell is connected to the copper of another cell, they form a battery of two cells. The electrodes or conductors are in this case to be joined to the remaining zinc (negative) and copper (positive) poles. The wires may be simply soldered to the plates, twisted around them, or fastened in binding screws soldered to the plates. It must be particularly observed that in forming any electrical connections the wire extremities should be perfectly clean —a coating of oxide greatly retards the current.

When the two cells are thus connected together it is said that they are joined or combined for electro-motive force, because both their electromotive forces are added together, and it would be found that two cells thus connected could deposit copper, or do other work, in a much greater resistance than one cell could overcome. The quantity of electricity actually passing will remain as for one cell, but the power to push that quantity through a resisting medium has been doubled.

Another statement, connected with these cells, should be made here; it is that each cell offers a given *resistance to its own current.* It is of much importance to understand this. The liquid between the plates is but a poor conductor, and therefore offers resistance to the passage of the electricity given off at the zinc plate. This resistance is called the *internal resistance*, because it is within the cell, and not between its poles without. Every cell has its internal resistance. Two cells added together present a double measure of internal resistance, and can for that reason give a current in a higher resistance than one cell. When the cell is small, its resistance is great, but diminishes directly as its size is increased. Thus a cell of what is known as "quart size" will present an internal resistance twice as great as one of two-quart size, and so on. The current will also increase in proportion in an interpolar resistance equal to that of the cell. Hence, to obtain the maximum current, or effect, a cell can give, *the external should equal the internal resistance.*

The *electro-motive force* has been mentioned before, but it remains to be shown that it is *not* dependent upon the *size* of cell. A pair of thin copper and zinc wires immersed in the solution will exhibit the *same electro-motive force as a pair of plates a yard square.* The work power or current will, of course, be very different.

Electrodes.—These are the conductors which lead the current from the battery to the depositing vessel. The positive electrode, as has been explained, is always that which leads from the negative *plate* of the battery. It is the conductor which leads the current *into* the depositing vessel. The negative electrode is connected to the positive *plate* of the battery, and leads the current from the depositing vessel after it has (it may be said) done its duty there. These conductors should always be of stout copper wire or of strap copper, and should ordinarily be insulated, or covered with some non-conducting material, as gutta-percha or tarred twine.

When the electrodes are metallically touched together, the circuit is complete through them, and it will be found that a magnetised and freely hung parallel needle, brought near to the wire, will immediately tend to place itself across the wire. This is Oersted's celebrated discovery.

The wire is indeed endowed with marvellous properties; wound around a piece of iron, it causes it to instantly become powerfully *magnetic*—this is *electro-magnetism*; it ceases and begins with the current.

When the current exerts no effect upon outside bodies, the wire and battery are heated by its energy: the energy of the current must, in short, be expended upon *something*—heating the circuit, creating magnetism, deflecting needles, decomposing electrolytes. Just in proportion to the amount of effect the current exerts *outside* the battery does the latter become less and less heated. *The battery is simply a portion of the circuit*, and should always be considered in that light.

The Anode.—The anode, as has been before explained, is the positive pole or *plate* by which the current *enters* the solution to be decomposed by it. The anode employed in electro-typing is always of *copper*; it is a plate of copper, about as large as the electrotype to be formed. It has two chief functions: it leads the current into the solution, and it also *dissolves, to make up for the abstraction of copper* to form the electrotype or deposit. It may thus be simply said that the anode both serves as the positive pole and keeps the solution in working condition.

The Electrolyte.—This is the solution from which the electrotype is deposited. It must be composed of at least one conductor and one non-conductor; two non-conductors or two conductors together, as an electrolyte, will *not* be decomposed by the current; in our case it is a solution of cupric sulphate, acidulated with a little sulphuric acid. It is contained by a vessel or vat, called the *depositing* vat. When the copper is set free from this solution, and made to adhere to the cathode, it is said to be *deposited.* The deposit is thus the *electrotype.*

When a current of electricity is made to pass through the electrolyte, the real work done is as follows:—The components of the electrolyte are *resolved into two distinct groups*—electro-negative elements (such as acids and metalloids), which move towards the anode; and electro-positive elements (such as metals and alkalies), which move towards the negative plate. In plainer words, the sulphuric acid of the sulphate of copper moves towards, and combines with, the anode, dissolving it and forming fresh sulphate of copper; the copper thus set free appears at the negative plate or cathode, and adheres to it.

Strictly speaking, the atoms mentioned cannot be said to *move* towards the plates; the real action consists of a *series of interchanges*, forming a *molecular chain* from one plate to the other, and the force necessary to set all the molecules composing the chain in motion forms the resistance of the electrolyte—thus the longer the chain the greater the resistance. The ultimate liberation of the components does not take place in the body of the solution, but at the surfaces of the plates. The whole action is (electrically) but another phase of the well-known and oft-repeated law that positive repels positive, but attracts negative; and negative repels negative, but attracts positive. If, after the cathode has received a deposit of copper, and the anode is proportionately dissolved, we reverse the direction of the current through the solution, the whole action is repeated at reverse ends of the vessel. Thus the cathode now acts as an anode, and the anode as a cathode; the result is that the cathode loses its deposit, while the anode regains it. This has reference to a reversal of current, which is apt to take place, and which is discussed further on.

Several distinct phases of current work in the electrolyte are discussed under the separate heads succeeding the following paragraph:—

The Cathode.—This is the plate which receives the deposit in the solution, or at which the electro-positive components appear. The cathode in electro-typing practice is the mould upon which the copper is deposited. It must always be remembered that the cathode is connected to the negative *pole* (zinc *plate*) of the battery. As the mould to be deposited upon is usually of some non-conducting substance, such as wax or gutta-percha, it must receive a *conducting surface.* The substances best adapted to this purpose are plumbago and nitrate of silver. Plumbago of the first quality is a good conductor of the current; it is reduced to an impalpable powder, and carefully brushed upon the mould until the surface presents a uniformly coated appearance, when all excess of the powder is blown away: an apparatus known as the black-leading machine is used for this purpose. The mould, when its lines are very delicate, is usually coated with precipitated silver, which forms an excellent conductor. The connection to the mould is either obtained by bedding a wire in it direct, or the mould is made in a metallic frame, to which the wire is connected.

Minor Effects of the Current on the Electrolyte.—The solution is always raised in temperature by the current, according to the resistance offered by the conducting component. The chemical action, apart from the power of the current, consists chiefly in the formation of cupric sulphate by reason of the sulphuric acid being liberated directly at the surface of the copper anode. Neither of the gases, oxygen or hydrogen, is set free under ordinary conditions. If gas should appear arising from the plates, it is an indication that the current is too strong.

The depositing vessel offers a counter force to the current; it acts, in fact, as a kind of condenser of force, which may be simply proved by including a galvanometer in the circuit and suddenly withdrawing the battery, either by cutting it out of circuit by means of a loop wire, or by opening the circuit and reclosing it, leaving out the battery. A counter rush of current will mark the truth above enunciated. If this counter strain, which is constant, and depends upon the materials in the cell, be greater than the electro-motive force of the battery, no work will be done in the depositing vessel. This counter force may be due to two causes: it may be partly caused by the *condensing* action of the molecules, or by a phenomenon generally called *polarization*, which may be observed as follows:—An amalgamated zinc plate, and a smooth, clean, copper plate, when plunged in acidulated water and connected together, form a single voltaic cell, and it will be observed that the hydrogen gas given off by the copper plate exhibits a tendency to cling to it; before the plate is quite "polarized," or covered with a film of gas, the cell has practically ceased to act; this is due to the counter force offered by the electrified hydrogen. The phenomenon of polarization is often erroneously supposed to be due to the *plate itself*.

Polarization, however, is much more troublesome in the battery than in the depositing cell. When the copper plate of a battery cell is covered with a granular coating of copper the gas is allowed to escape with greater effect, and the cell gives a more regular current. In Smee's battery, silver plates, coated with a granular layer of platinum, are employed with very good results.

Among the minor effects of the current or chemical action in the solution may be noted the peculiar movements which are observed to take place in the liquid. When the current is passing through the solution, that portion of the liquid in immediate contact with the anode becomes heavier than the surrounding liquid, by reason of the continual addition to it of fresh cupric sulphate off the anode. The result is that it sinks, and produces in time a heavier stratum of liquid at the bottom of the cell. But the liquid around the cathode becomes, for the reverse reason, light, and rises to the surface, so that the result is a continual redistribution of the electrolyte. It is for this reason, also, that the solution is seldom stirred, or needs to be remixed.

Decomposition of Different Solutions.—Electrolytes are decomposed and their metals set free in the proportion of their atomic weights, or multiples of these weights; or, in other words, those substances which are set free with the least expenditure of energy are most easily decomposed, and are always decomposed first when in company with others of a different nature.

This law can be worked out for all the metals by ascertaining their atomic weight, and dividing that by the corresponding valency, which will give the electric equivalent required, thus:—

$$\frac{\text{Atomic weight}}{\text{Valency}} = \text{Electric equivalent;}$$

or, for copper, we may take the same formula,

$$\frac{63 \cdot 5}{2} = 31 \cdot 75;$$

or, for siiver,

$$\frac{108}{1} = 108.$$

Hence, a current that will deposit one electric equivalent of copper (31·75 parts) will in the same time set free one equivalent (197) of gold and one of silver (108). We can, therefore, give to each element its value electrically, and find by the above process its relation to other elements.

As iron is employed in electro-typing, it may be of use to give its electric equivalent here, 28·, which shows that a given weight of iron is not so quickly obtained with a given current as a given weight of copper. This teaches that the law of definite electro-chemical action is based upon the electric equivalent, and space need not be occupied in giving lists of figures, which can be readily worked out.

Relation of Current to Work.—When a solution of cupric sulphate is subjected to the action of a current, the metal is reduced upon the cathode, but not always as a tough and malleable coating. A piece of bright steel dipped into the solution will receive a red coat of copper, but a piece of zinc will cause the metal to be precipitated as a black powder. These actions, first discussed by Alfred Smee, F.R.S., are very instructive, because the same effects can be produced by means of a current derived from a battery.

When a *weak* current of electricity is passed through the depositing solution, we obtain a coating of copper upon the cathode, but it proves to be of a highly crystalline and brittle nature, and, therefore, useless. When a *strong* current is so passed, the metal is deposited in a state of black granules, loose, and lacking both adherence and cohesion. When a medium current is tried, the metal is deposited in the tough malleable (sometimes termed "reguline") state required. The weak current may be represented by a small and feeble cell, the strong current by a large battery, and the medium current by a pair of ordinary cells. But the range within which good metal can be obtained is considerable.

The same effects can also be obtained with a *given* current in *different* solutions. Thus, if we employ a saturated solution, the copper will be crystalline. If we dilute the solution with from two to four times its bulk of water, the metal is deposited in the malleable state, and if we dilute still further, we obtain granular deposits of copper.

From these facts the conclusion that the deposit depends for its quality both upon the solution and upon the current must be drawn and remembered.

With a weak solution and strong current a black deposit will be given when hydrogen appears at the negative plate (cathode). Crystalline deposits are obtained when the current is weak and the solution strong.

The best working condition is that which exhibits a strong *tendency* to produce gas at the cathode in a strong solution. The anode and cathode should have equal surfaces.

Effects of Large and Small Electrodes.—Taking a given current of suitable electro-motive force (call it, according to the unit, 2 webers per second), we can deposit, say, 40 grains of copper per hour. Now this is the law to which we must attach most importance. This weight of copper will be deposited *irrespective of the size of the cathode.* On a wire it would form a thick coating, but we should obtain the required 40 *grains per hour.* On a plate it might be a coating thinner than tissue-paper, but 40 *grains per hour* would be given. Very little more need be said upon this point, but it is a law which would appear to give much trouble to electro-depositors to thoroughly apprehend, and is nowhere clearly explained in the earlier treatises on electro-metallurgy.

When the anode is made too small, the resistance of the bath (solution) is thereby increased, and an insufficiency of copper is dissolved off. When it is made too large the resistance is diminished, but too much copper is dissolved off. Therefore, except in cases where there is an excess of cupric sulphate in solution, or a deficiency, the anode should not be smaller or larger than the cathode.

Resistance of the Solution.—A saturated solution of cupric sulphate offers great resistance to the current; area for area, it is as 16,855,520 compared with 1 for pure copper—thus a cylindrical body of the solution 1 inch in diameter and 1 foot long would offer the above enormous resistance, if a similar body of pure copper offered a resistance of 1. The addition of a little sulphuric acid increases the conductivity of the solution, as does also an increase of temperature. The *great area* of the solution provided in the vat, however, compensates for its low specific conductivity, by affording a vast number of paths throughout which the current may divide its passage. A resistance of from 1 to 5 ohms (p. 8) is usually offered by the space between the plates (anode and cathode). When the plates are large they may be separated to a greater distance than when they are small, because the area of liquid covered is greater in the first case.

When the current is too strong, and gives a black deposit, it will yield good malleable metal if the anode and cathode are taken further apart, because the resistance between them will be augmented, and will absorb the excess of current, *but this method of working is wasteful;* it is much more economical to diminish the expenditure of zinc in the battery, and so reduce the current at its source, as explained under *The Depositing Process*, p. 190. When the current is too weak, and yields a crystalline, pale deposit, it may be strengthened by placing the plates nearer to each other. For perfectly flat plates, up to 6 inches square, the distance between anode and cathode should never be *less* than 2 inches.

Simple Immersion Deposit.—When iron, steel, tin, lead, and type-metal are simply dipped into a solution of cupric sulphate they receive a coating of copper; a simple voltaic tendency is, in fact, set up by the partial decomposition of the liquid, and a thin coating of the metal, sufficient only to perfectly cover the surface, is deposited. Thus simple immersion deposits are almost always exceedingly thin. Metals that coat themselves by decomposing the sulphate of copper solution cannot be coated by a battery current in that solution; therefore an alkaline mixture, such as copper dissolved in cyanide of potassium, in which these metals will not coat themselves, is employed.

Single Cell Depositing Apparatus.—This was the apparatus first employed in the deposition of electrotypes, and it is even yet in use for small work, although greatly inferior to the separate current process. It consists simply of an outer vessel of stoneware or glass if small, and of wood coated within with gutta-percha if large. A convenient size for experiments is a cylindrical vessel containing about two quarts. An inner vessel, of porous earthenware, is also employed; it should be about half the diameter of the outer cell, and a little higher. These porous earthenware vessels serve the purpose of diaphragms for separating two liquids, but allowing the current to pass; they used to be made of various materials, including wood: a brown-paper cell may be employed for temporary work. Full information concerning these cells is given in Chapter III. To complete the apparatus, a rod or plate of zinc, amalgamated (p. 57), is provided, with a wire cast into its upper extremity. This zinc rod is placed in the porous cell, in water slightly acidulated with sulphuric acid. The outer vessel is nearly filled with a solution of crystals of sulphate of copper (the sulphate may be dissolved in warm water), Fig. 2.

If the end of the wire attached to the zinc is dipped into the solution, the action immediately commences, and copper begins to be deposited upon its extremity. In a short time a knob of pure copper will be found attached to the wire. If the copper appear dark, the current may be assumed to be too strong, and the zinc may be raised a little, or the wire's extremity may be placed further away from the porous cell. If the copper deposit appear pale and crystalline, the wire should be brought nearer to the cell, or the current should be strengthened by adding a few more drops of acid to the contents of the porous compartment But the copper may be deposited upon a flat plate, a ball, or upon *any conceivable shape of cathode.* A deposit thrown upon a medal or coin will, when chipped off, exhibit the marvellous accuracy of the electrotype.

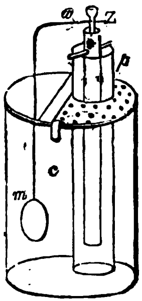


Fig. 2.—Single-cell Depositing Apparatus.

A copy of a coin or medal taken on gutta-percha or wax, while warm, and well blackleaded, can be connected to the wire by heating the latter and pressing its extremity into the mould at the back; the blacklead must, of course, conduct up to and upon a portion of the wire, otherwise the circuit will prove incomplete. The copper will be thrown upon this mould, commencing at the extremity of the wire, and gradually spreading over the face of the mould. In a day or two the copper will be thick enough to stand being withdrawn, after gentle heating. It will be found to be in every respect an accurate copy of the original as far as the moulding extends.

But these processes are fully described in Chapters VI., VII., and VIII.; they are mentioned here to furnish a definite idea of the method by which an electrotype can be produced, and not to give practical instruction in the art. The whole arrangement employed to illustrate the single-cell method forms a galvanic pair, the zinc, as usual, being the positive element, and the mould the negative. The current arising from the surface of the zinc forces its way through the porous division, decomposes the copper solution, and sets the metal free upon the wire and mould.

Methods of Making the Solution.—The ordinary electrotype solution for the single-cell process consists simply of cupric sulphate crystals (p. 31) dissolved to saturation (until the liquid ceases to dissolve) in warm or cold water. It should be kept in this saturated condition, as the copper is abstracted, by adding crystals.

The solution for separate current methods consists of a saturated mixture as above, with one-fifth of water, acidulated with one-tenth its weight of sulphuric acid added.

These solutions may be made by passing a current from a copper anode to a copper cathode through a mixture of sulphuric acid and water. This is known as the *battery process;* it is more expensive than the ordinary method, and has no compensating advantages.

Separate Current Process.—This is the method alluded to throughout the foregoing instructions. It consists in the employment of a voltaic cell or battery, a thermo-electric pile or dynamo-electric machine as the *source of electricity.* The vessel in which the deposit is obtained is usually a vat, properly prepared, and fitted with metallic rods and screws for hanging the anode and cathode, besides securing the ends of the wires from the battery or other source of current. The mould, being properly faced and connected, is slung upon the negative rod or pole of the battery (connected to the zinc plate). The anode, a plate of copper, is connected with the positive pole; both hang beneath the surface of the solution at such a distance apart as may suit the strength of current passing. The copper is deposited, at first slowly, around the connection, from which it creeps all round the edges and over the entire surface of the cathode.

This is the process as applicable to flat plates only. When the objects (cathodes) are round, or when they must be deposited upon from the interior of a mould, different arrangements are adopted, but the actual process is the same. The details are sometimes complicated to the extent of employing twelve or more anodes, and numerous "leading-wires," as the cathode wires are termed. These details, upon which so much depends, should be separately studied under the different heads in the following chapters.

Compound Vessel Process.—This process of depositing the copper consists in the use of a long trough depositing cell, divided into a number of distinct and separate compartments. Each compartment contains a copper anode. The object is to obtain a number of separate electrotypes at one operation; with a view to this, each compartment also contains a mould to be copied. One battery or cell is employed to work the whole arrangement, the conducting connections being as follows:—The positive pole of the electric source is attached to the first anode; the same compartment contains a mould or cathode, which is connected to the succeeding anode; in this way the second cathode is connected to the anode in the next cell, and so on to the end of the series, when the remaining mould is connected with the negative pole of the battery.

This arrangement cannot be said to possess any noteworthy points of advantage. The original idea attaching to it was that, by the expenditure of one equivalent of zinc and acid in the battery, one equivalent of copper would be secured at each cathode throughout the compound depositing cell, but the mere fact that the *resistance* increases in direct ratio with the number of cathodes exposes the absurdity of this expectation. And, moreover, the equivalent of copper would be deposited not in *whole* at *each* cathode, but would be *distributed equally between them.* Hence, a number of electrotypes, to be done at one operation, should be slung upon a common rod, and exposed in the solution before a large anode. The current will thus be more evenly distributed between them, and the resistance will prove much smaller.

The Galvanometer.—The construction and use of the galvanometer are described at p. 92. This instrument, although not at first much used by electrotypers, should be perfectly understood by them and constantly at hand. Its function is to detect a current and *measure its strength.* Rule-of-thumb work, in which no galvanometer or other instrument is ever employed to inform the operator as to the magnitude of his currents or resistances, is surely contemptible enough in the face of the fact that a fraction of the skill and intelligence displayed by its votaries would make them masters of both principles and galvanometers.

CHAPTER II.

Metals used by the Electrotyper.

THE two chief metals employed in the practice of electro-typing are copper and iron; the former is universally used for the body of the electrotype, and the latter is superficially deposited upon the better class of printing surfaces produced by electro-deposition, with the effect of rendering them more durable. (See p. 2.)

Copper.—Pure copper possesses a beautiful red colour; it is moderately hard, but tough and malleable. Symbolically it is represented in chemical formulæ by *Cu;* electrical equivalent, 31·75; atomic weight, 63·5; specific gravity, 8·9. Copper is, next to silver, the best known conductor of electricity; Dr. Matthiessen gives its conductive power as 99·9, as compared with 100 for silver. This metal is, therefore, admirably adapted for the purpose of making electrodes, and also for hooks and rods, which, with screws, form the fittings of an electro-typing vat.

Salts of Copper.—The ordinary salts of copper are the sulphate, commonly called blue vitriol; the nitrate; the chloride; the suboxide; the protoxide, acetate, and cyanide. The sulphate is the compound of copper most extensively used. It may be made by heating chips of copper in sulphuric acid until the compound is nearly dry, washing the product in boiling water, and evaporating and crystallizing the solution so obtained after filtration. But it is usually more economical to purchase the salt. Its price varies from fivepence to sixpence per pound. When the salt is pure it presents the appearance of large crystals of a deep blue colour. An admixture of green indicates the presence of iron, which must be avoided with much care. The following test will render the presence of even minute quantities of iron manifest:—Dissolve a sample of the salt in distilled water, and add ammonia with stirring until the blue precipitate obtained is redissolved. Allow it to stand some time, and pour off the clear portion of the liquid. Pour a large quantity of distilled water on the residue, and allow it again to settle. If iron be present, it will appear as a reddish powder in the lower part of the liquid. From the sulphate some of the other salts of copper may be prepared.

Nitrate of copper may be conveniently made by dissolving copper, in chips, in nitric acid, and evaporating and crystallizing the solution.

Chloride of copper may be made by dissolving the metal in aqua regia (a mixture of one volume of nitric acid in two and a half of hydrochloric acid), and treating the solution as before.

Acetate of copper is known in commerce as crystallized verdigris, and is so cheap that it seldom pays to make it at home.

Cyanide of copper is a salt of considerable importance to the electro-depositor; it may be made as follows:—To a solution of copper sulphate add, with agitation, a solution of cyanide of potassium until a precipitate ceases to fall. The operation must not be carried beyond this stage, otherwise the precipitate will be redissolved. Allow the precipitate to settle and pour off the liquid portion; wash the precipitate once or twice and filter. The resulting salt has a pale green aspect, and is highly poisonous; the operation is also somewhat dangerous unless conducted in free air or in a draught-chamber: both solutions should be cold.

Electrolytic relations of Copper.—In a saturated solution of ammonia copper is electro-positive to iron, and the tendency is powerfully augmented if a solution of sulphide of ammonium be substituted for the simpler liquid. In a solution of oxide of copper in liquid ammonia, or in a saturated solution of ferrocyanide of potassium, it is positive to iron, but only for a short time—it then becomes negative. In a saturated solution of bichromate of potassium, or a strong aqueous one of sulphide of potassium, it is increasingly positive up to the point of boiling. This last liquid has a similar effect on brass (Gore).

Electrolysis of Copper Salts.—It is found that a solution of chloride of copper is not so readily decomposed by the electric current as one of the nitrate, but more readily than the sulphate; chloride of copper is, moreover, one of the most difficult liquids to deposit copper from, and the metal is apt to assume a spongy form. The same fault applies to the acetate and hyposulphite, and they all need a strong current to effect their decomposition.

Immersion Deposition of Copper.—Iron, lead, tin and zinc become very slightly corroded in a solution of sulphate of copper, and consequently receive a thin coating of the metal; but antimony, bismuth, copper, nickel, silver, platinum and gold are not acted upon and receive no deposit. The reverse holds true on passing a current, for then the first class of metals cannot receive an *adhesive* deposit, while the second class receive an adhesive deposit of any desired thickness.

The slight coating of copper secured by iron and steel upon simple immersion in a solution of copper sulphate has very wide practical applications. An appearance of copper is thus imparted to vast quantities of iron and steel goods, while in other instances the initial coating serves as a good base upon which gold or silver may be deposited to any required thickness by the separate current process. A solution suited to the coating of cleansed steel and iron articles may be made by mixing three quarts of water with one of hydrochloric acid and one ounce of solution of copper sulphate. The objects should be immersed and removed and washed several times during the operation.

The Single Cell Process.—As explained at p. 25, copper may be deposited upon any suitable surface by the single cell process. A saturated solution of sulphate of copper is well suited for use in such combinations, and the copper yielded, under favourable conditions, is always of very fine quality and texture. The sulphate solution may be employed to deposit copper upon any of the metals that do not decompose it.

Quality of Deposited Copper.—Deposited copper is not necessarily pure; zinc is very often thrown down with it, and other metals, according to the current passing. From a solution of the pure salts, however, copper may, especially by the single cell method, be obtained absolutely pure.

When the current is too strong, the copper has a tendency to be porous and rotten, or to be deposited in the form of coarse grains. When the current is too feeble, a crystalline deposit is obtained, which is both hard and brittle. Tough malleable copper, in the "reguline" state, is obtained when the current and resistances are properly balanced. Electro-deposited copper, when precipitated under favourable conditions, is superior in ductility and strength to the purest rolled samples.

Iron.—Chemical symbol Fe; atomic weight, 56; electrical equivalent, 28; specific gravity, 7·8. Iron, as employed by the electrotyper in the process of "steel facing," is generally derived from the salts of the metal. Iron is usually very impure, and needs careful working to obtain the clean deposits required.

Salts of Iron.—The common salts are the protosulphate, commonly called green copperas; peroxide (jeweller's rouge), protochloride, carbonate, and perchloride. The protosulphate is so cheap as to render its preparation at home unnecessary; but it is made by heating fine iron wire in diluted sulphuric acid until the solution is saturated, and then evaporating. The operation should be conducted as much from the influence of the air as possible. The residue is a green crystalline salt, freely soluble in water. By employing hydrochloric acid instead of sulphuric, the protochloride of iron is secured; it is similar in appearance to the protosulphate, and is also freely soluble in water. Perchloride of iron is made by adding nitric acid to a solution of the protochloride and evaporating to crystallizing point; this is a reddish salt.

All the salts of iron are liable to change, and most of them, as the protosalts in solution, absorb oxygen from the air.

Electrolysis of Iron Solution.—Iron may be deposited from many of its salts, but the protochloride and protosulphate are most in favour for purposes of "steel facing." It may be deposited by simple immersion, but this process has had no extended application. A separate current is always employed. All iron solutions should be protected as much as possible from the influence of the air.

Brass.—This is an alloy of copper and zinc, and as it is only used in imparting a hard facing to some kinds of electrotypes, it need not be spoken of at length here. It may be remarked, however, that zinc and copper together always require a strong current to deposit them as an alloy. If a weak current be employed, the copper will be deposited and not the zinc, but if the current be sufficiently strong, both metals appear in combination at the cathode.

Nickel.—This is a hard and brittle metal. It is generally obtained in commerce in the form of grains. Its electrical equivalent is 29·5; it always needs the expenditure of a good deal of battery power to set it free. Nickel has not yet been successfully rolled, so that anode plates are usually made in the form of cast slabs; an anode of platinum foil may, however, be used in setting free small quantities from a solution, as described in Chapter IX.

Zinc.—This metal is chiefly employed in voltaic batteries; its nature is therefore described in Chapter III.

Backing Metal.—This is used as a "backing" for electrotype shells when they are not sufficiently rigid to serve their intended purpose. It is usually made by melting together: lead one pound, tin one ounce, antimony one ounce. The lead is melted first and the other metals added. It is usually best to thoroughly mix them by granulating, which is most readily accomplished by slowly pouring the melted mass through a wire net into a bucket of water. The grains are collected and may be again melted and divided to insure perfect mixture. This metal, with more or less tin and antimony, may be purchased ready for use.

"*Tinning Metal.*"—This is also known as solder, and is very useful to the electrotyper in joining shells, as well as preparing their backs for the reception of backing metal. It may be made by melting together equal weights of tin and lead and granulating once or twice as directed above. It is usually considered best to preserve the tinning metal in the form of grains in a suitable vessel, free from dust.

Other and less important metals are employed by the electrotyper, but they will be found spoken of under the different sections in connection with which they are used.

CHAPTER III.

The Source of Electricity.

THE current-electricity necessary for the practice of electro-typing is usually derived from one of the following three sources :—

1. *Galvanic Batteries*, as yet the cheapest and most convenient source of electricity applicable to operations of moderate extent.

2. *Thermo-Electric Batteries*, in which current is due to heat usually derived from gas, charcoal, or coke.

3. *Dynamo-Electric Machines*, generally driven by steam-power, the economical and efficient action of which has brought them into use in most of the important electro-typing establishments.

This section of the art of electro-typing will, therefore, be treated under the above three heads, each separately and distinct from the other two. Each source of electricity has its advantages, a brief summary of which will be found at the end of each section.

GALVANIC BATTERIES.—The main principles of the galvanic cell, with which it is necessary that the electrotyper should be familiar, are discussed in the first chapter of this volume (p. 10 *et seq.*).

Simplest Type of Cell.—A pair of plates, zinc and copper, immersed separately in one vessel of acidulated water, form a cell of the zinc-copper description. These plates may be of any size, from one square inch to several feet, but a convenient size of this cell should contain about one gallon of liquid, with plates 8 by 4 inches. When the wires from such a cell as this are joined to a galvanometer, a powerful rush of current is indicated; which, however, soon begins to fail in strength.

The zinc-copper cell may, nevertheless, be arranged to give a very useful and cheap current for electro-typing purposes by following the author's plan of depositing a granular coating of copper upon the copper plate by the usual electrotype process. The action of the rough surface is similar to that of the platinum on silver employed in Smee's battery (p. 43).

It is much better, however, to arrange the cell on the principle of construction employed by Smee, that is, two amalgamated zinc plates (p. 57) should be employed, clamped to a dry wooden bar, with a plate of rough-surfaced copper between, but not touching, them.

Or the cell may be arranged on the principle of the Wollaston battery, which has been so extensively used in electro-plating and typing. In this type of construction one large copper plate is employed, bent into a U shape, the ends of which are clamped to a bar of varnished wood crossing the top of the vessel in which the liquid is kept. Through the wooden bar slides a plate of amalgamated zinc hung in position by a cord and counterweight passed over a pulley. The advantage of this construction lies in the facility with which the zinc may be withdrawn from the liquid when the cell is not in action, and the obvious convenience of being able to regulate the amount of current by immersing more or less of the zinc plate at will. The copper plate may be made in two halves and connected together at the top, which is the better way of the two, as it permits of more free circulation of the exciting liquid. The distance between the plates may be from one-half to two inches, according to their size. The most suitable exciting liquid is usually considered to be one part of sulphuric acid to ten of water.

When the battery is thrown out of action for some time the copper plates should be removed, as they are liable to suffer corrosion, and, consequently, liberate small quantities of sulphate of copper, which act upon the zinc and set up local action and consequent waste. When in use the copper should be kept clean, and this is generally most easily accomplished by renewing the rough copper coating referred to above.

The Carbon Plate.—An excellent and cheap cell may be constructed upon the above model by substituting carbon for copper. The variety of carbon employed in galvanic batteries is that known as graphite, or gas carbon. It is *not coke;* it forms as a scale upon the interior surfaces of the gas retort in the process of evolving gas from the richer coals. In the bulk, as chipped from the retorts at gas works, it is extremely cheap. It should be of a clear grey colour, very hard, and as regular and close in texture as possible. *Plates* of this battery carbon will last for any number of years, but they are difficult to cut from the most suitable quality of the substance.

These carbon plates are, however, easily procurable at reasonable rates, and may with every advantage be employed as a substitute for the more wasteful copper in the copper-zinc battery. Their good points may be summed up as follows: small first cost, high conductivity (when of moderate thickness), highly granular everlasting surface, and fitness for remaining constantly in the liquid when the battery is out of action.

In order to provide a good electrical connection with those plates, they should be provided with a cap of copper, electro-deposited, at the upper end. This may be done in the single cell (p. 25) by tying the zinc wire to the carbon, and allowing an inch of its end to dip into the solution of cupric sulphate. In an hour or two a coating of copper will be secured, when the end must be dipped in boiling water to remove all traces of the copper salts; it should then be provided with a terminal screw (p. 56) by soldering, and the cap well protected by a coat or two of black varnish applied while the carbon is hot. Fitted in this way these plates, in conjunction with amalgamated zinc plates, form a really good cell, which may be worked with a variety of excitants or by dilute acid simply. (See "Carbon-Zinc Cells," p. 52.)

Two large carbon plates, with one zinc between them, as in Wollaston's cell, constitute a useful cell; but the construction may be extended, and several zinc plates between carbons may be arranged between a pair of long varnished wood bars extending over the top of the containing vessel. The force is increased by platinising the plates.

Size of Plates in Batteries.—This must be regulated by the extent of the work to be done. A good general rule to follow is to have the battery plates a little larger than the work to be deposited upon. Of course the *number* of plates when they are all joined together to form substantially one cell, will materially affect the size of *each plate*, as it is the *surface exposed in each cell* that ought to be considered and made equal to the surface to be deposited upon. The *number of cells* will have reference, of course, to the electro-motive force, which must be regulated to the resistance of the circuit (p. 13), and is entirely independent of the size of each cell.

Platinised Silver Plates.—What Smee really effected in his battery was to provide, in silver, a highly electro-negative element, coated with a rough layer of platinum, admirably suited to the *dislodgment of hydrogen*, which clings to a smooth surface and practically puts a stop to the action of the battery.

Smee's battery (Fig. 3) is thus composed of a simple pair of zinc plates (amalgamated) having between them a thin sheet of the platinised silver. It is a type of cell which has been more extensively used than any other in the art of electro-typing. Its first cost is rather great, but the most expensive item, the silver plate, will last for about fifteen years if care be taken, and the platinising be periodically carried out.

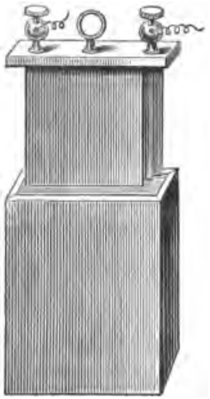


Fig. 3.—Smee's Battery-plates raised.

It is false economy to procure the silver plate very thin; it should have a thickness at least equal to an ordinary "visiting card." Its cost, of course, depends upon its weight, but it may be procured ready rolled at about the market price of silver. A very useful size for ordinary electrotypers' work is 12 by 8 inches, which, if of a good stout sheet, will cost something about £3. This price, although high, will of course be in great part recovered when the plate is unfit for work and sold for old silver.

To platinise the silver plate an arrangement exactly similar to the single cell depositing vessel (p. 25) should be provided, and it is advisable to employ a vessel large enough for the outside cell to allow of the silver plate being immersed in it without being bent.

The porous vessel may be of the round form, but when the plate to be coated is large this is a disadvantage, inasmuch as the action must necessarily proceed with greatest rapidity in the immediate vicinity of the round porous cell. For this reason it is better to employ a flat cell, but failing this, two porous vessels may be brought into requisition, with zincs connected together, to distribute the rate of deposition evenly over the surface of the silver plate. Of course a separate cell may be used to give the current, and the plate may thus be platinised in an ordinary depositing vessel, employing an anode of platinum foil. According to the single-cell method, which is more generally applicable, the porous vessel should be nearly filled with acidulated water (1 to 10), and a rod or plate of zinc suspended in it. A wire should lead from this to the silver plate, which, with the porous vessel, should be placed in the outer cell containing acidulated water (weak), in which saturated solution of bichloride of platinum should be present (1 part solution to 30 water). In a few minutes the deposition will be observed to darken the plate, and while it proceeds the mixture should be gently agitated with a glass rod. When the plate appears dark brown or nearly black it may be removed, or, perhaps, a better guide is to allow the plate to remain from seven to eight minutes in the solution.

Silver plates, previous to being platinised, should be washed in caustic soda solution or cleaned off with glass paper. After the completion of the process the plate should be dried and carefully handled while being placed in the battery frame.

In order to protect the silver plate from injury, and give it some firmness, it is usual to mount it in a frame of wood, but this is a bad, dirty, and troublesome method. The plate should be stiffened by four clamping-pieces of sheet-lead, bent double, and hammered down so as to grasp its edges firmly. This is quickly done and will outlast the plate, while wood is a constant source of trouble. These edges should be warmed, and a coat or two of pitch varnish, or ordinary good japan, applied to them.

The usual and most convenient construction of a Smee cell is somewhat similar to that of the copper-zinc description already spoken of. Taking a single pair only of the Smee type as an example, the silver plate is made fast in a groove cut in the bar of wood forming the support across the exciting vessel. The wood should be of some hard description, but good mahogany, baked dry and well varnished, answers perfectly. The full width of the wood bar may be one inch, or rather more for large cells. The zinc plates may be slightly longer and wider than the silver element to afford some protection to it in case of accidents. They should be well amalgamated, and selected in accordance with the hints given at p. 56. One zinc plate is placed at either side of the bar, parallel to the silver, and both are clamped in that position by means of one or two ordinary battery clamps, which serve at the same time to connect the two plates as one and to provide a means of fastening the electrode. The electrode from the silver plate, and which should be soldered to it is led out through the wooden bar, and may either terminate in a binding-screw or lead direct to the depositing vessel. The "couple" is then ready for immersion in the dilute sulphuric acid, which may be contained in any convenient vessel. Round glazed earthenware pots to contain about six gallons are best adapted for the immersion of single couples. These jars are easily procurable, and are chiefly manufactured for the English market, expressly for batteries, by Messrs. Doulton, of Lambeth.

In some establishments, however, when the plates are of a larger size it is found best to arrange the requisite number in a teak trough lined with gutta-percha, lead, or cement. A very cheap and good kind of battery-containing vessel may be made from teak, well jointed and thoroughly coated inside with marine glue (p. 148).

The strength of dilute sulphuric acid generally employed as an excitant for the Smee battery is one part (volume) of sulphuric acid to ten parts of water. Additional information necessary for the working of Smee batteries will be found further on (p. 61).

Double-Fluid Cells.—The cells previously spoken of are all excited by one fluid only, but much greater constancy and regularity of current is secured by the use of two liquids, separated by a porous partition.

It is, indeed, remarkable that the double-fluid cells, with all their advantages, have not been so extensively employed for electro-typing purposes as those of the more simple construction. The cause doubtless lies in the fact that double-fluid cells were not known so early or so well as Wollaston's and Smee's, for had Daniell's type of generator been universally understood by electrotypers, Smee's would have long ago given place to it, to the advantage of both man and art. Several electrotypers have, it is known, tried the Daniell and Bunsen cells, and some have given them up in favour of Smee's. This was due, no doubt, to the fact that the double-fluid cells were not understood or worked with that skill which should be part of the art of the electrotyper.

That no cell yet invented can compete with the Daniell for constancy in working, and great power to keep up a given current, few who are acquainted with the question will deny, and that it is quite as cheaply maintained as the Smee, even electrotypers will readily admit, while its first cost is obviously a trifle.

A Daniell cell for the purposes of the general electrotyper can be made up from very ordinary materials. The outer vessel is of the usual glazed earthenware, to contain about eight gallons of liquid; the inner one, half its internal diameter, of porous ware. In the outer cell is placed a roll of sheet copper in a solution of cupric sulphate, and in the porous vessel a cylinder or large rod of amalgamated zinc, in the usual dilute sulphuric acid. Zinc rods for Daniell cells may be cast from any scraps at hand. A smooth and slightly tapering tube, oiled within, should be used as a mould, as it is important to secure as smooth a surface as possible, otherwise it is almost impossible to effectually amalgamate cast zinc.

It is almost needless to point out the obvious advantages such a combination presents to the electrotyper. The salt and excitant are of a kind constantly in use in his business and are therefore cheap, as they are purchased in quantity. The metal he is also acquainted with. The battery is not half so wasteful of zinc as Smee's, and its positive element may be amalgamated with greater ease. It may be excited by a solution of common salt, or even sulphate of zinc, and exhibits a constant and vigorous current with all excitants. Its first cost is about one-tenth that of Smee's.

Some electricians prefer to place the zinc in the larger receptacle, and the copper in the porous cell. In either case the cell will be found to keep in action for days together without any attention, and when weakly charged has been known in the author's experience to deposit copper from a bath for a full month without once being looked to.

In order to secure these desirable results it is necessary to caution the reader to avoid the mistakes made by others of his art, by following the hints given herewith.

Heat both top and bottom of the porous cell and paint over about half an inch with japan varnish or hot pitch. Treat the top of the zinc and copper cylinder similarly. Observe that the copper cylinder cannot touch the porous cell. Observe also that the zinc is *suspended* in the porous cell by means of a wooden cover or a bar of wood across the top; the zinc must not rest on the bottom of the cell. Never allow crystals of cupric sulphate to lie in the bottom of the outer vessel, and preserve its solution at a constant strength by adding crystals to a quantity kept upon a circular shelf made on the copper cylinder. Do not allow the crystals to come in contact with the porous cell. Keep the liquid in the porous cell a little higher than that in the outer cell. Examine and clean the zinc rod when it becomes dirty. Chip off any nodules of copper that may appear upon the exterior of the porous vessel, and cover the spot with a touch of varnish. Thus, with less attention than is given to a Smee cell, the Daniell will yield a stronger and a more constant current, producing copper of very superior texture and toughness. For general information regarding the Daniell cell the reader is referred to pp. 59—62.

Bunsen's cell (Fig. 4) is more generally applicable where a very strong current is required, as for "steel facing" and the deposition of brass and nickel. Its construction is similar to Daniell's, but the zinc occupies the outer vessel, in diluted sulphuric acid, while the negative element is of gas carbon (p. 41) in the form of a square or round bar, placed in the porous vessel, which is nearly filled with strong nitric acid.

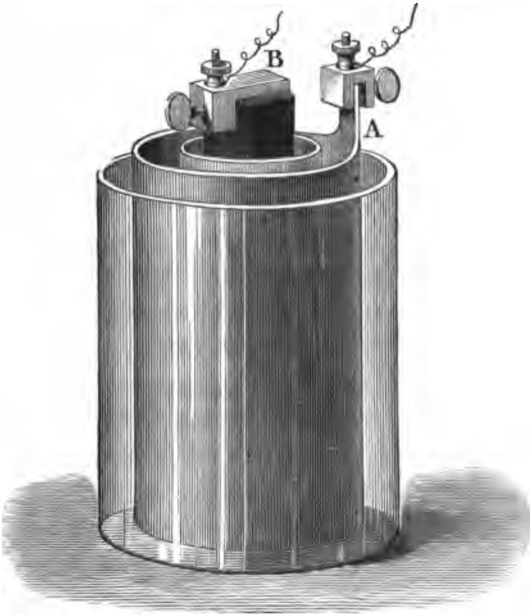


Fig. 4.—Bunsen's Battery.

The current yielded by this battery is very vigorous, because the internal resistance is very low, probably not one-twentieth of that exhibited by an equal-sized Daniell cell. When fully charged, its action continues almost constantly for four or five hours. Much care is necessary to keep the zinc amalgamated, and to avoid allowing any of the nitric acid to drop into the outer cell, because it sets up destructive local action. The carbon rod should be headed with an electro-deposit of copper as suggested at p. 42, and should likewise be well protected around the heading by repeated coatings of pitch, applied while hot. The first cost of the Bunsen cell is comparatively low. A pair of them, of two-gallon size, usually provides ample strength of current for the steel-facing process, as well as for brass and nickel.

A very useful, cheap, and clean battery may be made by simply charging the Bunsen differently; thus, place in the porous cell a saturated solution of bichromate of potash, strongly acidulated with sulphuric acid, and in the outer vessel a solution of common salt. The force of this combination is very high, while the resistance is less than that of the Daniell cell; it is more cleanly than the Daniell, but in constancy of current it is inferior.

Grove's cell is in some respects superior to, and is more compact than, Bunsen's, but its first cost is very high, by reason of the price of the platinum plate employed in place of the carbon block. It is usually made in the form of flat cells, and may be employed in any work where a powerful current is necessary.

Carbon and Zinc Double-Fluid Cells.—The efficiency of these batteries, several forms of which have recently been introduced, is chiefly due to the excellent depolarising qualities of the bichromate of potash employed. The electro-motive force is equal to that of the Bunsen battery, and the internal resistance is comparatively small.

From the experiments and observations the author has been able to make, it would appear that a really good cell for iron deposition can be generally employed, made on the one-fluid principle, at a cost very much under that of Bunsen cells. The proposed battery can be made by clamping a pair of carbon plates, one on either side of a zinc plate, after the construction of a Smee. The excitant which has been found to answer best is known as Anderson's salts, which the inventor has described in his patent as made by adding oxalic acid to a solution of bichromate of potash until effervescence ceases, and then slowly evaporating the solution, when the crystals of the oxalate of chromium and potash will be obtained. These salts are, however, obtainable commercially. This is used with both single and double cells. To charge the single cell, this salt is dissolved in water strongly acidulated with hydrochloric acid along with a few crystals of the bichromate. The current is very vigorous and well sustained.

The double-fluid cell is, however, preferable on account of its long-continued action. A porous and an outer cell are employed. The zinc, in the form of plate or rod, is placed within the porous cell, in a solution of muriate of ammonia, and the carbon, in the form of a plate, occupies the outer cell, in a solution of the salt described above in connection with the single cell.

When the solution in the outer cell begins to show signs of weakness, more crystals of bichromate of potash should be added. The inventor, however, describes in his patent an ingenious arrangement, by the aid of which the crystals may be made to add their strength to the battery as fast as is required, and by which the strength of the cell may to a great extent be regulated. It consists of an earthenware or glass tube, covered at the lower end with platinum gauze and containing the crystals; this tube is clamped at such height within the cell as to allow the salt to dissolve fast enough to supply the consumption; its action thus depends upon the greater or less depth of crystals below the surface of the solution.

These cells, although they have not as yet been extensively tested and used in electro-typing, exhibit every good quality applicable to the practice of the art, and well deserve a careful trial by all electrotypers. The electro-motive force is slightly higher than that of Bunsen's cell. (See also p. 63.)

Conductors from Batteries.—Copper is universally employed for the conductors between the plates of batteries, and between the poles and the vats. It is very flexible and ductile, cheap, easily obtainable, and forms one of the best conductors of electricity. It is generally employed in the form of straps, or stout wire, as main conductors between the battery and vat. Thin wires should never be used, because they offer a high resistance to the current and consequently retard its passage. Copper wire of the No. 10 size, by the Birmingham wire gauge, is well suited to most purposes, but straps are often considered more convenient in use; they should never contain less copper per foot than a wire of the above size. The sling wires will be spoken of at greater length in connection with the vat fittings, but it may be here mentioned that No. 10 copper wire is a suitable size.

One very important point to be observed is that the conductors make *absolutely clean metallic contact* with the terminals of a battery, otherwise much power may be wasted on the resistance offered by a dirty connection, as it has been shown that dirt or oxides offer an enormous resistance to the passage of a current. In the case of employing long leading wires, as from batteries situated at some considerable distance from the depositing vat, the wires should be still stouter, or two twisted together employed. In connection with this, it may be useful to state that the resistance of a conductor increases directly with its length, and varies inversely as the area of its cross section. No. 10 wires, or straps of equal weight per foot, may be employed between battery and depositing vessel over any distance not exceeding 100 feet. The resistance of this length (100 feet) will be about one-fifteenth of an ohm, or less.

All conductors between battery and vat should be insulated with gutta-percha, or tarred twine.

Cotton-insulated wire, baked and steeped in melted (solid) paraffin, forms a damp-proof and inexpensive conductor.

Terminals.—These are the various kinds of connecting screws employed by the electrotyper (Fig. 5). They are made so as to clamp the conducting wire to the pole in order to provide a good electrical contact. As a rule terminals are screwed or soldered to the elements of a battery. The chief thing to observe is that they shall make perfect metallic contact with the plates, and that the subsequent action of the battery shall not corrode the contact. Clamps are usually of brass, like screws, but in some cases it proves more economical in the end to employ copper clamps. All terminals should be fitted with thumb-nuts large enough to allow a good pressure to be exerted in screwing them down upon the wire.

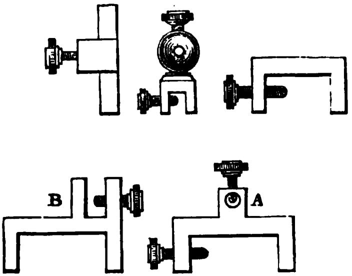


Fig. 5.—Battery Terminals.

Zinc for Voltaic Batteries.—Whenever possible, stout rolled Belgian zinc should be used in batteries. Cast zinc is not only much more likely to contain impurities, but its surface is usually so bad as to preclude the possibility of amalgamating it (p. 57). Sheet zinc, suitable for batteries, should never be thinner than one-eighth of an inch, but it may be thicker with advantage. As received from the rolling mill its price may be reckoned at about fourpence per pound. As the amount of zinc dissolved in the battery bears a proportion to the weight of metal deposited in the vat, it may be assumed that the battery plates do not last long when in constant use; it is, therefore, economy to keep a large quantity of plates in stock, cut to size.

To cut Zinc.—Zinc may be readily divided to the required sizes by first marking off the dimensions in lines, deepening these with a scratch or two of a graver, and running mercury into the cut, when the plate may be readily broken over the edge of a table. If any difficulty be experienced it may be removed by repeating the process on the opposite surface.

To bend Battery Zincs.—This metal exhibits the peculiar property of softening very readily by a slight increase of temperature. Therefore zinc plates just taken out of boiling water may be easily curved and bent to the required shapes over a former of wood or iron; a wooden mallet is also useful to the workman in curving the cylinders.

Amalgamation of Zinc.—This process is very simple, but it is of the greatest importance. If absolutely pure zinc could be obtained for batteries, the necessity for amalgamation would not render itself manifest. If any foreign ingredients are present in the zinc the action of the battery is seriously interfered with, and great waste goes on. The impurities found in zinc are commonly compounds and particles of iron, tin, and lead, which set up miniature local cells with the other parts of the zinc plate by reason of the electrical relations existing between them (p. 10). To prevent the formation of these minute and wasteful local currents, a coating of mercury is spread over the zinc (which "takes" the mercury readily), forming an amalgam; this coating serves to connect the zinc and impurities in one whole conducting surface, and prevents the differences of electrical condition from manifesting themselves.

To amalgamate the plates it is necessary first, if the plates be new, to wash them in hot caustic soda solution, so as to remove the greasy film imparted to them at the rolling mills. A flat vessel is then partially filled with dilute sulphuric acid, and upon it is also poured a little of the best quality of mercury procurable. The plate is dipped in the liquid and the mercury rubbed on with a pad of tow or other suitable substance. The workman should take particular care to cover every portion of the surface. When the plates present a uniform silvery appearance they may be set upon edge to drain, after which they are ready for placing in the battery. Much care should, of course, be taken to insure that only pure, or nearly pure, mercury shall be employed, as mercury adulterated with lead and other metals will frequently be found to do more absolute harm than good.

Copper Plates for Batteries.—Sheet copper, about $\frac{1}{32}$nd of an inch in thickness, is almost universally employed as plates and cylinders to form negative elements in batteries where copper is used. The copper cylinders of Daniell cells may be even thinner than usual, as, instead of wasting away, they continually *increase* in stability, by reason of the added deposits of copper. Elements of this metal, in whatever battery they play the negative part, should be kept clean and bright. Those of Daniell's cells are always sufficiently clean while the combination is in action. Dirty copper plates or cylinders may be effectually cleaned by heating to redness and plunging in dilute sulphuric acid; rubbing with a wire card is also very effectual. The various shapes required are readily cut from the copper sheet by means of shears. The metal "takes" solder readily; the flux employed should always consist of resin.

Containing Vessels for Batteries.—The best vessels for use in the electro-typing laboratory are of brown glazed stoneware. For the separate cells, where one pair of elements occupies one vessel, cylindrical pots, suitable for Daniell, Bunsen, and Smee cells are well adapted. They are procurable in sizes to contain from a pint to many gallons of exciting liquid.

In cases where a number of moderate-sized plates are employed, to give a Smee or other cell of very large total surface, troughs of lined teak wood answer very well.

Porous Vessels for Batteries.—All necessary sizes of porous cell are now procurable. They are made from red or white earthenware, and are unglazed; they thus allow the current to pass, but separate the two liquids employed. Much care should be bestowed upon the selection of these cells, for upon the kind and quality of cell materially depends the internal resistance (p. 13) of the battery, and also its capability to maintain a current at a given strength. For Daniell cells, to remain in action for considerable periods, the white variety is best adapted, because they are somewhat hard, and prevent the two solutions from readily intermingling. In Bunsen batteries the red cells may be used with advantage, because they are generally soft, and offer little obstruction to the passage of the current during the periods over which the cells are in action. Porous cells may be procured in both cylindrical and flat shapes, to suit the different forms of generators. All cells should be tested for porosity before being used in the battery; each one should be filled with water, and the effect upon the exterior surface noted. If the water should run off, the cell is too porous for any purpose, but if it appear as a heavy dew upon the exterior in the course of an hour or so the vessel may be considered fit for use in Bunsen batteries; the hardest cells, through which, however, the water should appear in time, may be employed for the more constant Daniell and bichromate batteries. Some of the best cells are glazed around the bottom and around the brim. This is a great advantage, and should be universal, as it to a great extent prevents the creeping effects of endosmose from bringing copper into the zinc compartment.

Solutions for Batteries.—The exciting liquid in most batteries is diluted sulphuric acid, in which the amalgamated zinc element is immersed. The strength of this mixture depends upon two things: the quality of zinc and the state of amalgamation. The strength varies also according to the amount of current required. Really good zinc, well amalgamated, will stand a very strong acid mixture without wasting, but bad zinc, poor in mercury, will waste in the weakest liquid. The actual strength employed may be taken to vary from one volume of acid to thirty of water to one of acid to six or eight of water. For use in Smee and Daniell cells a good strength is one to ten. In Bunsen cells it may be as strong as one to five, if the amalgamation be in good condition.

The sulphuric acid employed should be of the best quality only, but even this frequently contains small quantities of nitric acid, which is very destructive in the zinc compartment. To detect nitric acid, dissolve indigo in pure sulphuric acid, and add this solution to the suspected sample, boiling the mixture. If the indigo should disappear in the boiling, nitric acid may be assumed to be present.

It is always false economy to use any quality but the best nitric acid for Bunsen's negative cell. The most concentrated should be employed, and it should also be free from hydrochloric acid. Good nitric acid may be used to charge the cell three or four times; that is, supposing the battery to be set up now and again for iron facing purposes, perhaps occupying half an hour at each operation. After the first time of using the acid is found to have turned to a reddish colour. When again used it may turn to green, and finally to a clear liquid. After this it is useless, and may be thrown away.

The various solutions of salts employed in the batteries described or mentioned in this book should, it may be generally assumed, be as pure as possible. Information regarding cupric sulphate, for use in Daniell's cell, will be found at p. 31. As the strength of a battery to a great degree depends upon the state of its solution, attention should be paid at intervals to the liquids and to refresh them with new crystals.

In the action of the Smee, Daniell, and some other cells, the sulphate of zinc formed in the process gradually accumulates in the solution until it becomes quite thick and heavy. This condition can only arise from complete want of attention, and in porous cells especially should be avoided. When the sulphate of zinc is allowed to accumulate in quantity, it offers great resistance to the current, and should be withdrawn in part or whole as the occasion may require. Smee cells in full constant work generally make the solution quite heavy and unfit for work in a week or less, but much depends upon the attention paid to it, such as adding a little water, removing the zinc plates and washing them, adding a little acid, and so on.

Local Action in Batteries.—This term is sufficiently comprehensive, and has been explained at p. 58, in connection with the subject of amalgamation. Local action always exhibits its effects in the form of dark patches upon the clean amalgamated surface. These spots will be found partly honeycombed, and a difficulty is very frequently experienced in covering them again with mercury. In order to avoid altogether the worst effects of local action, the plates should be amalgamated frequently. Zincs several times amalgamated, however, should be handled carefully, because they become very brittle. The residue of the mercury left in the bottom of battery jars should be preserved for future use. Much care should be taken, when the zinc plates are frequently amalgamated, to avoid allowing any mercury to touch the silver, which it renders liable to crack.

Electro-motive Force of Batteries.—The electromotive force of some of the more useful batteries here mentioned may be judged of from the following figures from Latimer Clark's "Electrical Measurement": —

Grove's	100
Bunsen's	98
Daniell's	56
Smee's (when not in action)	57
Smee's (when in action) about	25
Copper-and-zinc cell	46

The *current*, with which the electrotyper is chiefly concerned, will depend in a very great degree upon the resistance (internal) of the cell. This may vary from one-tenth of an ohm (p. 8) in large Bunsen cells to four or five ohms in Daniell cells. It will be observed that the force of the Smee cell is much higher when tested with the negative wire put to earth and the positive wire connected to a condensing electrometer, than when the circuit is actually closed in useful work.

In this treatise a full statement of the relations existing between electro-motive force resistance and current cannot be given; for such information the reader is necessarily referred to some good text-book of electricity. It may be useful, however, to give a few particulars concerning the cells with which the electrotyper is likely to deal.

It must always be borne in mind, in calculating battery power for any given work, that the electro-motive force and the resistance determine the current. Thus, a cell of high electro-motive force and low resistance will give, through a good conductor, a much stronger current than a cell of equal force but much higher resistance. Hence, one Bunsen cell, by reason of its small internal resistance, will yield, in a circuit of low resistance, a much stronger and more effective current than two Daniell cells coupled together, but the latter, in a circuit of high resistance, would do more work than the Bunsen cell. The most common and comprehensive expression relating to these laws is *that the external (interpolar) resistance should equal the internal resistance.*

Hence, batteries of comparatively high internal resistance may with economy be employed in all electro-typing work of high resistance, and where the surface to be coated is but an indifferent conductor, such as blackleaded gutta-percha or wax.

Electro-motive force should be regulated to suit the resistance, but in most cases the E.M.F. of *one* Smee or Daniell cell will prove sufficient in copper depositing. When, however, the mould to be deposited upon is of an undercut design, and therefore presents much resistance, requiring pushing power in the current, it is necessary to employ *two* Smee or Daniell cells, or two of the zinc-carbon bichromate type described at p. 52.

To *increase* or double the *electro-motive force*, the pairs must be separate and distinct from each other, and not mounted in one trough or cell. Then, by simply connecting the copper (or silver) of one pair to the zinc of the other, and taking the leading wires for the vat from the remaining zinc-and-copper (or silver plate) terminals, the force is doubled. It must be remembered, however, that the effective *size* of the battery remains as one cell, and is not in any way increased. The *pushing power* of one cell has been added to that of a second, but the power to yield a current remains as for one cell. The *internal resistance* has been doubled; that is, both resistances have been added together, and consequently the combination of two cells is more powerful against high resistance than one cell. Electro-motive force may thus be increased to any required extent by continuing to join up cells as above, or *in series*, as it is termed.

The reader, on consulting a good text-book of electricity, will find that the electro-motive force of a cell is expressed in terms of a unit of force, called the "volt," from Volta. This electro-motive force is only slightly less than that of *one Daniell cell;* in fact, the Daniell cell is frequently taken as equal to one volt. Now, if we employ a volt force (the unit), or one Daniell cell, and arrange the size so as to give a very small internal resistance, we may assume that in electro-typing we have a resistance of one ohm (the unit of resistance, equal to about 6 feet of 36 gauge copper wire), and our current will therefore be equal to one *weber* per second (weber, the unit of current, or quantity), and the result will prove that we are depositing copper *at the rate of* 17 *grains per hour.*

This can actually be done by employing a pretty large Daniell cell, and a good conducting solution. Therefore, the electrotyper can calculate very nearly how much copper he can deposit per day, when he has a good idea of his total resistance.

It may prove useful to the reader to give in terms of the unit, in connection with the above statement, a list of the forces exhibited by the different cells he is likely to employ in his art. The figures may prove of use also in gaining a rough estimate of the work being done in the circuit. But it should be borne in mind that all particulars relating to the laws of the circuit given herewith, are intended to be studied in connection with those in some such work as Jenkin's "Electricity and Magnetism" (Longmans), and not to be taken without further inquiry into the actual causes at work in the electric circuit.

Cells.	Probable internal resistance. (1 gallon size).	Electro-motive force in volts.
Daniell	1·5 ohm	1·079
Smee (not in action)		1·098
„ (in action)	·5 „	·482
Copper-and-zinc	·5 „	·886
Bunsen	·2 „	1·964
Bichromate carbon cell (p. 53)	·6 „	2·028

To increase current or quantity, it is only necessary to enlarge the cell, or, which comes to the same thing, join up two or more cells in parallel circuit; thus all zincs to one electrode and all coppers to the other. When a cell is doubled in size, its resistance is halved. Then the resistance is in direct ratio with the surface of plates active in the cell (provided, of course, that the liquid shall always remain the same, both in conductivity and space to be passed through).

"Making up" Batteries.—Much space is usually devoted in works on electricity to the subject of joining up cells in series and parallel circuit, and to the discussion of effects from batteries differently arranged. These instructions, although they are merely extensions of the rule for increasing the electro-motive force at p. 65, and also that upon which the quantity of current depends, as above, are very useful to those who employ considerable

numbers of cells in their operations. The electrotyper, however, seldom has occasion to use more than two cells to gain the force he requires, so that particulars relating to numerous cells would be misplaced here. The force of current required for the several specific purposes mentioned in this treatise is clearly stated in the section devoted to "The Depositing Process," Chap. VIII.

Care of Batteries.—The economical management of his battery is a matter of much importance to the electrotyper, since zinc and excitants are expensive, and because irregular working not only leads to inferior work, but to costly waste.

With special reference to the Smee cell, care should be taken to remove the plates from the solution when the day's work is over, and to examine and wash them. They are examined chiefly to find whether the amalgamation has failed, and to detect marks of local action. Black patches should be scraped clean and re-amalgamated.

The exciting solution should be stirred at least once in every two days to equalise its density, and a small quantity of sulphuric acid and water added. It may then be used until it becomes of an oily consistency, which will be indicated by the zinc sulphate crystallizing upon the plates. The silver plate should be replatinised about every four or five months, according to the duty it performs.

In the use of sulphuric acid for batteries, it is highly important to avoid pouring water into acid, as this frequently causes an explosion dangerous to the eyes. Acid should always be added to water, and this not too fast, because great heat is spontaneously produced.

Porous cells, whenever used, should, as often as practicable, be kept soaking overnight in water to clear out the pores, which are apt to get clogged up with crystallized salts. The crystallization of salts will also crack cells that are allowed to become dry for any considerable length of time after use. All porous cells permit of the gradual intermixture of the two separated liquids in batteries. This is called *endosmose*, and is the chief cause of the failure of current in the Bunsen cell after a few hours' work. The word endosmose is also used in this work to indicate the peculiar creeping action of crystallized salts, especially in reference to the Daniell cell.

Cost of Battery Working.—Theoretically, an equivalent of copper should be deposited for each equivalent of acid and zinc consumed in the battery, so that, according to this rule, all cells should cost, in working, the same price. In practice, however, this is never attained, and it then becomes a question which is the most economical cell with which copper may be deposited.

Laying aside the fact that the silver in Smee's cell is gradually destroyed, this type of generator may be taken to be as inexpensive in working as any, but the deterioration of the silver plate raises its cost to something much higher than that of the Daniell or carbon-and-zinc bichromate cells.

Five shillings a year may be reckoned as about the cost of silver in a very large Smee cell. The Daniell cell might, however, exhibit an equal expense for porous pots, if carelessly attended to. But apart from the silver plates and porous cells, the question turns upon the consumption of zinc and sulphuric acid, these being the two chief substances used in most voltaic batteries.

Absolutely correct working is never attained; indeed, it would be easy to prove that from the very nature of the operation of batteries it never can be attained; but we can still determine within narrow limits the amount of copper which we ought reasonably to expect to realise by the expenditure of a pound of zinc and acid in the battery. For every equivalent of zinc $\left(\frac{65}{2} = 32{\cdot}5 \text{ parts}\right)$ and every equivalent of sulphuric acid $\left(\frac{98}{2} = 49 \text{ parts}\right)$ expended in the battery, we should, theroetically, be able to obtain one equivalent $\left(\frac{63{\cdot}5}{2} = 31{\cdot}75 \text{ parts}\right)$ of copper in the electrotype. Thus one pound of zinc (nearly) should give us one pound of copper, but the usual consumption in the best batteries now used exhibits a discrepancy of nearly half a pound; hence from one and a quarter to one and a half pounds of zinc will be consumed to each pound of copper deposited, besides the consumption or absorption of sulphuric acid in due proportion.

It may readily be deduced from these observations that the deposition of one pound of copper will cost us, with zinc at fourpence per pound and sulphuric acid at three half-pence, about sixpence for electricity alone. Thus the *total* cost of an electrotype plate by battery current, weighing one pound, would not be, and in practice is not, less than two shillings. By dynamo-electric machines the cost would probably be less than one shilling and sixpence.

THERMO-ELECTRIC BATTERIES.—In several instances where heat is either obtainable without expense or at a merely nominal cost, thermo-electric batteries are employed, especially in France, with advantage. In the practice of the art on a large scale, however, the first cost of the thermo-electric piles places them in a position inferior to that occupied by voltaic batteries or dynamo-electric machines.

Principles of the Action in Thermo-Electric Batteries.—When two dissimilar metals are placed so as to touch each other, their opposite extremities being connected together by a wire, a current of electricity will pass through the wire so long as heat is applied to their point of contact. If the opposite extremities are artificially cooled, the current will prove more vigorous. This forms a *thermo-electric pair*, and in most respects it resembles a voltaic pair. A combination of two or more pairs forms, as usual, a thermo-electric battery.

The metals which have been found to exhibit this property in the greatest degree are bismuth and antimony. Bismuth is found to be the positive metal of the pair, and the current, therefore, passes across the heated junction to the antimony, which is negative. These metals, however, offer certain disadvantages in the construction of thermo-electric batteries, and have been replaced by others in various types of construction.

Clamond's Thermo-Electric Battery.—This is probably the best and most compact pile yet introduced; and where gas, whether from coal or light hydrocarbons, is cheap, it may be employed with advantage.

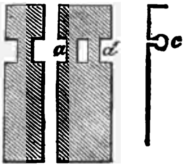


Fig. 6.—Iron Plate of Thermo-Electric Battery.

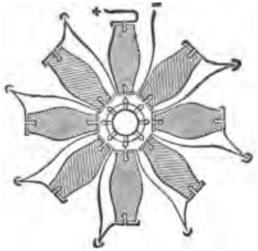


Fig. 7.—Thermo-Electric Circle.

The metals used by M. Clamond are, for the positive, ordinary tinned sheet iron, and for the negative, an alloy of antimony two parts, zinc one part. Each element is made up from a flat thick bar of the alloy (usually three-fourths of an inch thick, according to the size of each element) about three inches long, to which is connected in the casting, at one end, a flat strip of the tinned iron, which (Fig. 7) extends outwards to the opposite extremity of the bar, but is not connected to it. Several of these pairs are arranged in a circle on a temporary frame, all their junction ends being towards the centre, while the free end of each tinned-iron strip is connected to the end of the bar succeeding it. In this manner a circle of elements is connected together in a way similar to the joining up of batteries in series (Fig. 7).

Several of these circles are laid one above the other, the separation between them being formed by a coating of powdered abestos and a solution of silicate of potash. When the pile is thus built up it is secured by cast-iron rings and connecting rods in a compact form. The elements are arranged like the spokes of a wheel, so as to give free effect to radiation. The central aperture common to all the layers of element rings is utilised as a chamber in which the junctions may be heated by gas.

A perforated tube of porcelain ascends into the chamber. The gas is passed into the tube, mixed with air, burns in blue jets through the perforations, and keeps the junctions of the elements at a uniform temperature (Fig. 8).

These piles are obtainable commercially. One of the large ones, burning ten cubic feet of gas per hour, will, the inventor states, when coupled for quantity, deposit about one ounce of copper per hour. This, of course, refers to copper deposited upon a metallic anode, and certainly cannot be done upon blackleaded moulds at half this speed. The inventor gives the electro-motive force of the 100 bar pile as 5 volts, when coupled for quantity.

This is a very good result, and as the internal resistance is only a little over 1 ohm, it will be observed that such a thermo-electric battery is equal theoretically to about four Smee cells of two-gallon size, coupled in series.

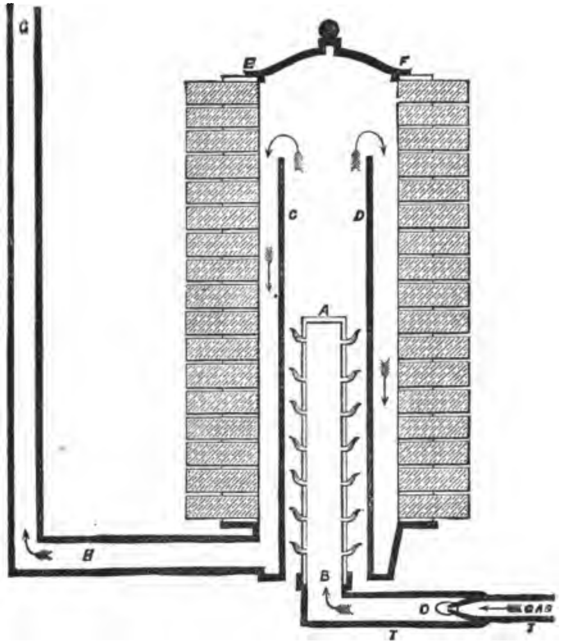


Fig. 8.—Section of Clamond's Thermo-Electric Battery.

Noë's Thermo-Electric Pile consists of small cylinders of an alloy of zinc and antimony as positive, and rods of German silver as the negative element. Mr. Gore, F.R.S., who has made some experiments with these piles, reports in their favour, stating that twenty of the pairs yield a current and electro-motive force equal to one Bunsen cell of about quart size. This combination would thus deposit about twenty grains of copper per hour.

Although electroplaters and typers have taken up these piles and have tried them, it has not been done with that vigorous spirit of progress which would lead their inventors to devote renewed energies to their improvement. There can be no doubt that these piles can be very materially improved and diminished in first cost if the users of batteries would only give their inventors encouragement.

The chief advantage of the thermo-electric battery lies in the fact that once set up carefully it needs little or no attention, as the gas has only to be turned on and ignited to set it in action. It has not, to the author's knowledge, been determined to what extent these generators deteriorate by long continued use, but it is sufficiently clear that, although higher in first cost than batteries, they promise well to be a cheaper and cleaner source of electricity.

DYNAMO-ELECTRIC MACHINES.—These machines, although they are frequently indispensable in the deposition of large weights of copper, and in the abstraction of that metal from ore, will probably never wholly replace voltaic or thermo-electric generators, because to actuate them either steam-power or its equivalent, as gas engines or water motors, must be employed. Very many electrotypers are unable to obtain or afford this. The cost of depositing copper by the dynamo-electric machine is very low, which soon repays the first cost of the machine in establishments where plenty of work can be constantly provided.

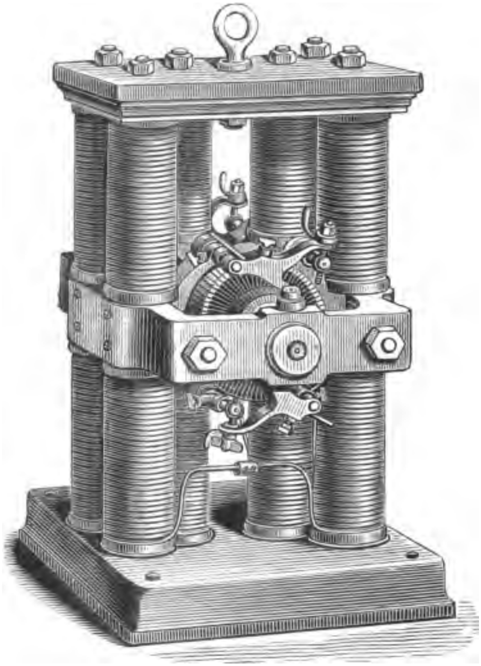


Fig. 9.—Gramme's large Machine.

Thus a good machine, requiring the driving power of a small gas engine, or from two to three horse-power, may be made to work two or more vats of solution at once, the current being divided between them in the ratio of their resistances.

All the dynamo-electric machines mentioned in this volume (p. 87) yield a very strong current, and may be made to produce numbers of electrotypes with great rapidity. Some of the machines produce currents equal to those from thirty large Bunsen cells. In the frontispiece are represented Maxim's and Weston's machines, adapted for electro-typing. Figs. 9, 10, and 11, represent Gramme's large and small machines and Wilde's long-armature machine.

Provided that there is an abundance of work to do, there is no more economical source of the large currents required than a good dynamo-electric machine. The first cost varies from £40 to £100, and upwards. This is speedily recovered when the apparatus can be kept at full work. The cost of maintenance, apart from motive power, is a mere trifle, as nothing is consumed in the action.

The currents produced by these machines are derived from electro-magnetic force; they are, in short, the effect of the motive power expended, as current electricity. A full statement and explanation of their action will, however, be found in the author's treatise on "Electric Light" (Lockwood & Co.), to which the reader is referred for special information respecting them. Much care should be devoted to the selection of a dynamo-electric machine to suit the work to be done. Some general directions will be found respecting this in the present section of this volume.

Establishing a Dynamo-Electric Machine.—Machines which require from three to ten horse-power to drive them are usually of a heavy description, and should be bolted either to wood beams secured to the earth or to masonry; the chief point is to secure a reliable fixture for such heavy machines, so that the vibration attendant upon high speeds

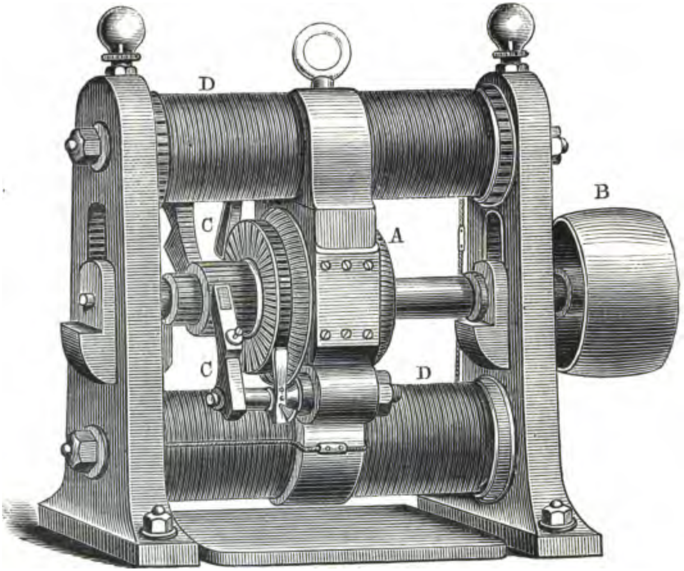


Fig. 10.—Gramme's small Machine.

may be reduced to a minimum. Much care must, however, be taken to set the machine in a *dry* situation, because damp not only attacks its naked iron work, but frequently penetrates and injures the insulating covering of the wires. Smaller machines than the sizes above specified may advantageously be fixed securely to a raised bench near to a wall, or to a stout wooden framework raised two or three feet from the floor level; it is important, however, to avoid a weak base-work as much as possible, because a shaky machine frame

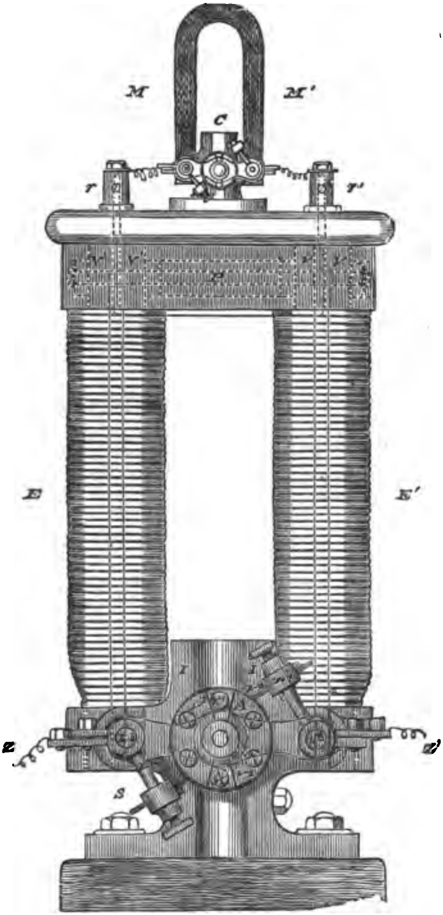


Fig. 11.—Wilde's Machine—End Elevation.

frequently sets the whole workshop into violent vibration, besides giving rise to much noise.

Most machines are simply provided with a fast pulley, so that in cases where the necessary counter-shaft is not sold with the machine, as in Gramme's apparatus, it is necessary to select a fast and loose pulley arrangement, of a size suited to give the required number of revolutions per minute to the machine. Broad and well-stretched bands should be employed, so that the tendency to slip may be reduced to a minimum. The number of revolutions given by the main shaft or engine should be calculated in relation to that run by the counter-shaft, and the relative sizes of both pulleys should then be considered to give the stated number of revolutions as an average, *while the machine is at full work depositing copper.*

Motors for Dynamo-Electric Machines.—The steam-engine is the best and cheapest motor for these machines, but both gas engines and water-motors are used. The chief peculiarity of the dynamo-electric machine is that to secure steady currents it must be driven steadily. This, however, in electro-typing may to a certain extent be overlooked. A gas engine which is not a very steady motor answers the purpose; those of Crossley Bros. are, probably, the best yet tried. Both gas and steam-engines should have a good margin of power over that absolutely required for driving the machine.

In many cases the machines may be situated near to a neighbour's engine, and the conductors led into the electro-typing room. This is frequently done. Sometimes the machine is fixed in a building 300 yards away, and the conductors led over the roofs, or along walls, to the depositing room. Most owners of steam-power have a sufficient margin of force to drive one or two machines, and the trouble is nothing, because the machine requires no attention except oiling and examination of the commutator every two days, while the cost to the electrotyper would be but a fraction of that necessary for the maintenance of batteries. Most newspaper engines are idle throughout the day, and many of them are hired for the driving of these machines, or employed by the owners themselves in this way.

Care of Dynamo-Electric Machines.—The first and most important precaution to be observed in the use of these machines is, *never allow them to run on short circuit*, because the excessive heat immediately produced in the coils frequently ruins the insulation.

The only other observances are, attention to the collecting brushes and oiling.

The brushes are two bunches of copper wire or sheet, fixed in holders, and pressing at opposite diameters upon the revolving commutator-cylinder of the machine. These brushes, by sparking and use, become worn, and must be slid further through the holder when required. The pressure upon the revolving cylinder should not be greater than is absolutely necessary to collect the currents without much sparking. Sperm oil should be used to lubricate the revolving cylinder, otherwise it will get cut up by the brushes, and much dust will be thrown off. The copper powder produced by wear should be wiped off the cylinder frequently.

The lubricating arrangements usually consist of needle oil cups, or ordinary syphon lubricators, and need no attention, but to be constantly supplied with sperm oil, free from grit. Owing to the high rate of speed, much care is, of course, necessary to avoid allowing the oil cups to run dry, or the oil-ways to get clogged up.

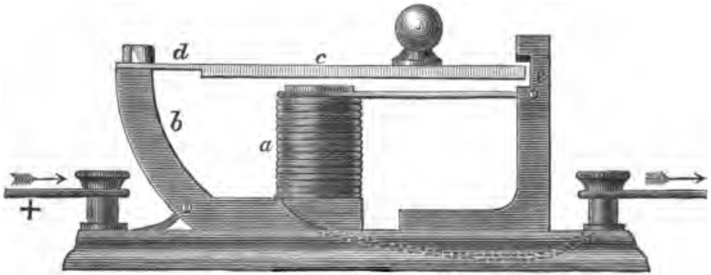
Regulation of Dynamo-Electric Currents.—In a large electro-plating or electro-typing establishment where a number of vats are employed, one machine is frequently arranged to supply them all. The arrangements should be somewhat as follow:—The vats should be ranged along one wall of the shop, at equal distances apart. The dynamo-electric machine should either be fixed on the floor just behind the central vat, or to a raised standard above it. The main conductors should consist of two stout copper rods or tubes, insulated from the wall by being fixed in dry wood brackets, and should extend from one end of the wall to the other. The conductors from the machine should be stout copper straps, screwed separately to the main rods. From each vat should extend a pair of electrodes fixed to the main rods, to conduct the current to the anodes and cathodes. By a little judicious care in arranging the sizes of vats and in laying out the resistance to be overcome, the current may be made to pass into each vat in the ratio of the size of its anode.

Resistance Coils and Shunts for Dynamo-Electric Machines.—With most machines suitable for electro-deposition sets of resistance coils or boards are supplied. These are designed so as to pass from the full current to any required fraction of it, suitable for the largest plates and the smallest electrotype. They act either by *shunting* part of the current by means of a short circuit wire, or by *resistance* to the current. It is obvious that when the machine is working through an added resistance in this way it costs as much as if it were in full work, and therefore it is more economical to work by means of shunts, which allow the required amount of the total current to pass back to the machine without entering the depositing vessel.

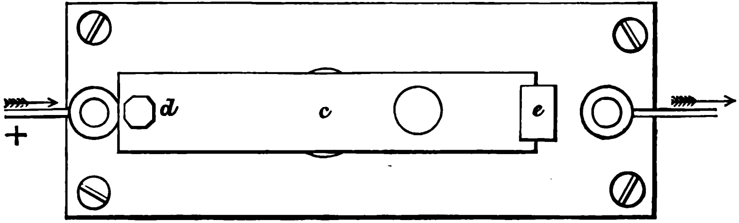
Some electro-depositors, on the other hand, allow the full current to enter the vat, and to compensate for its excessive strength place the anode and cathode further apart than usual. This, it will be observed, is but another way of reducing the current by means of resistance; it tends to heat the solution, and as the full current is used, the machine is as costly to drive as if the current were fully utilised.

Reversal of Polarity in Dynamo-Electric Machines.—When a machine has been depositing copper upon an electrotype, and is stopped without removing the latter from the bath, or disturbing the circuit in any way, *a counter electro-motive force is often set up in the bath, starting from the electrotype to the anode.* This small current may last for a short time only, but it is frequently sufficient to reverse the magnetic polarity or tendency of the machine. The result, when the machine is again started, is often sufficiently disastrous, inasmuch as the current, which should pass from the *anode* into the vat, does so by the *cathode* and re-dissolves it. Thus some of the best work may be destroyed. The facility with which the magnetic polarity of a machine may be reversed is explained when it is understood that the magnetism it depends upon for starting the current is merely the residual traces of magnetism left in the iron field magnets, so that a very weak current may reverse it.

To obviate the possibility of this occurring many devices, more or less clumsy and useless, have been invented; as a general rule they fail just when they ought to act, and are thus worse than useless. All that is really necessary is a device for throwing open the vat circuit as soon as the machine ceases to revolve. The author has successfully employed for this purpose a very simple arrangement (Fig. 12), which never fails to act, and may likewise be used as a circuit-interrupter. It consists of a cylindrical piece of iron, *a*, 1 by 3 inches, with a few turns of No. 10 copper (insulated) wire wound upon it. This electro-magnet is screwed to the base of the machine, or to a piece of iron bar, bent as shown at *b*. A stout iron arm, *c*, fitted at one end with a flat spring, *d*, is mounted above the magnet so as to be attracted by it against the spring when a current passes. The free extremity of the arm, when attracted by the magnet, butts against a brass stud, *e*. The conductor from one screw of the machine is connected to the arm, and to the brass stud *e*, one end of the magnet helix is made fast; the remaining end of the helix leads as one pole of the circuit to the vat. The whole forms a simple kind of electrical interrupter, with a resistance of about 100th of an ohm, or, practically, nothing; which signifies that it acts as no hindrance to the current.



ELEVATION.



PLAN.

Fig. 12.—Safety Current Interrupter.

Normally, the arm butts against a piece of ebonite fixed above *e*. It will now be apparent that if, under those conditions, the dynamo-electric machine be set in motion, it cannot begin to pass a current into the vat, or even give rise to one, because its circuit is *open*. This may be considered a great advantage in itself, because no action can take place, if so required, in the absence of the attendant, and the current cannot begin to pass until he presses down the arm. It will be observed that when the arm is pressed down to start the current its end touches the brass post and completes the circuit; the selfsame action makes the iron column magnetic, and it retains the arm in the required position so long as the current continues to pass without an interruption. But when the machine is brought to a standstill its current fails, the arm is, of course, released by the now weakened electro-magnet, and the circuit is without fail *thrown open*, and is safe enough, because no counter action from the bath can possibly enter the machine to reverse its polarity.

This arrangement is covered by no patent, and may be freely adopted by the reader. Its chief object is to render the throwing open of the circuit a certainty, in the simplest way, most easily controlled. It may, in the case of the machine being fixed at a distance from the electro-typing room, be fixed at any part of the circuit, preferably to the bench or wall near to the anode end of the vat, so as to be near at hand. It will be observed that should the circuit be opened by accident, even for an instant, the interrupter will rise and render its re-formation impossible without the knowledge ot the operator responsible for the work.

In one patented device of the kind alluded to above, a vessel of mercury is caused to rotate and to make contact by the rise of the metal; in another, a steam-engine governor with heavy balls and complicated mechanism is employed for the same purpose.

Dynamo-Electric Machines adapted for Electrotyping.—The machines manufactured by M. Gramme, of Paris, are in many respects best adapted for the purposes of the electrotyper. The smallest size is in length 18 inches, breadth 14 inches, and height 16 inches; its weight is 1½ cwt.; it should make 1,600 revolutions per minute. When arranged by the maker for quantity, it yields an electro-motive force equal to two or three Bunsen cells and a current of 40. The power with which it may be driven may be taken at from 1 to 1½ horse-power. Its cost at present is from £55 to £60, but the prices of all machines are falling. In ordering it should be stated that the machine must exhibit an electro-motive force of two Bunsen cells of half-gallon size, and a quantity of about 40. This is called arranged for quantity, but the same machine may be had wound for tension. The French depôt is in Paris (M. Breguet, 81, Boulevard Montparnasse). For fuller information concerning these machines the reader is referred to pp. 104—117 of the author's "Electric Light."

Maxim's machine is made in New York; it is in some respects similar to Siemens' machine.

Weston's machine is well adapted for the deposition of copper, but it cannot be said to be so economical of power as the improved Gramme and Siemens' machines. The cost of a medium-sized machine is £60. It absorbs about 2½ horse-power. The French agents are A. W. Kipling & Co., 55, Boulevard Saint Martin, Paris.

Schuckert's machine is the Gramme machine, as spoken of above, with one or two alterations of no moment. It is used in one or two establishments in London.

Wilde's machine (Henry Wilde, engineer, Manchester) has been extensively used for all kinds of electro-deposition. An idea may be formed of the power of those magnificent machines when it is stated that one of them (largest size) at the works of Messrs. Elkington, near Swansea, deposits four and a half hundredweights of copper in twenty-four hours. They are specially well adapted to service where the work is unusually large, as in the deposition of copper statues. Many of the figures which adorn the Albert Memorial in Hyde Park were deposited by Wilde's machines. (See "Electric Light," p. 93.)

Siemens' machine (Siemens Bros., 12, Queen Anne's Gate, London, S.W.) is well adapted to all purposes. A small size is sold at £60. In size and weight it is similar to Gramme's small machine. The power required is the same.

Much information of a technical character which cannot conveniently be embodied here, and relating to all kinds of machines, will be found at pp. 33—164 of the author's treatise on "Electric Light."

Measurement of Currents.

The practical electrotyper seldom measures his currents in the true sense of the term. He roughly obtains an indication of the strength of his battery in some arbitrary unit of his own, but more often by means of a kind of guesswork, based mainly upon the length of spark his circuit will yield when the two wires are suddenly separated, or by means of some rough surface (as a file) upon which one of the poles may be rubbed while the other is connected to it. He also frequently places the extremities of the wires upon his tongue, and can form some opinion, within wide limits, whether his current is abnormally weak or strong.

Although these rough-and-ready means of guessing at the strength of the current are not to be recommended to those who would advance in the art beyond mere manipulatory skill, they are, nevertheless, not to be despised. Some of the most remarkable electrotypes yet produced have been deposited by electrotypers who never used an instrument for measuring electrical currents.

An instrument for detecting the presence of a current is represented in Fig. 13. It is a simple galvanometer and is suitable for rough work. Under the name of "telegraph detector," it is obtainable commercially.

The strength of a current means its *work-power*. Thus, a current that will deposit two ounces of copper per hour is just twice as strong as one which will deposit only one ounce per hour. The recognised electrical unit of current is termed the farad; it is likewise known as a weber or veber, which is the term used by Mr. Latimer Clark in his "Electrical Measurement," and throughout this work. Its actual physical significance must be studied in some such treatise as Jenkin's "Electricity and Magnetism;" what we have to do here is to give some idea of its magnitude as expressly applicable to the requirements of the electro-depositor.

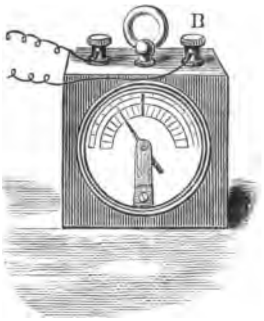


Fig. 13.—Common Current Detector.

A *Weber* per second is about equal to the current given by a Daniell cell of large size through a small resistance. This current will deposit about seventeen grains of copper per hour when the total resistance is one *ohm*.

The Ohm.—This is the unit of resistance to the current. Some idea of its magnitude may be gathered from the fact that 485 mètres of pure copper wire 1 millimètre in diameter at 32° F. would offer a resistance of one ohm. Or we may roughly take 6 feet of No. 36 Birmingham wire-gauge pure copper wire as about equal to one ohm. The internal resistance of a Daniell cell of about two-gallon capacity is sometimes rather less than one ohm.

The Volt.—This is the unit of electro-motive force, or the intrinsic pushing power of the battery. Some idea of its magnitude may be gathered from the fact that a Daniell's cell is frequently taken as about equal in tension to one volt, but the real force is 1·079 volt.

It will be particularly observed that, although these rough definitions of the electrical units are given here to aid the reader, their real meaning should be sought in a good text-book of electricity. The methods by which electro-motive force is determined should also be sought there. At p. 67 a list of the forces of the different cells employed in electro-typing will be found, and a comparative list at p. 63.

The internal resistances of cells cannot, of course, be definitely given, as they depend upon the size of the plates and upon the conductive power and thickness of the liquids within the cells. A comparative and probable list of internal resistances will be found at p. 67, but all such figures must be accepted with much caution, because they are apt to be very wide of the mark.

The current or actual quantity of electricity passing may, however, be determined in an absolute unit, or more conveniently in an arbitrary unit for use comparatively. These measurements may be made either by a galvanometer or a voltameter.

The *Galvanometer* is an instrument based upon the property of the current to deflect a parallel magnetic needle to a position at or about right angles to it. Thus, if a magnetized needle, or a compass needle, centrally supported or hung, be brought near to a parallel current wire, it will immediately deflect from its position to an extent *dependent upon the strength of the current.* Thus a weak current might deflect a needle 5 degrees, while a current twice as strong would deflect it about 9 degrees.

It will thus be observed that the current strength cannot be read direct from these galvanometers, as a deflection of 30 degrees does not signify that the current passing is only twice as strong as a current giving 15 degrees. The strengths producing the deflections are something approaching to the ratio of the tangents of the angles; but no definite information can be obtained from ordinary galvanometers unless their dials have been graduated by being compared with a tangent or sine galvanometer, the only instruments of this class capable of affording results which can be measured.

The mathematical explanation of the method by which readings from the tangent galvanometer may be corrected is to be found in most text-books of electricity. The instrument itself (Fig. 14) consists of a circle of strap copper or brass about a foot in diameter. The extremities of this hoop are furnished with connecting screws. In the centre of the circle is placed a small magnetic needle, usually furnished with a style or pointer of some light substance, such as coloured glass or aluminium. The copper circle is placed in a vertical plane, and the small magnetic needle occupies an horizontal one over a graduated card. The needle being small when compared with the inducing circuit, the result is that, lying in any direction, the needle holds the same relative position to the disturbing powers of the ring; so that the error of long needles, which applies to common galvanometers, is here almost entirely eliminated, and therefore the indications obtained are, *as the tangents of the angles*, read from the dial.

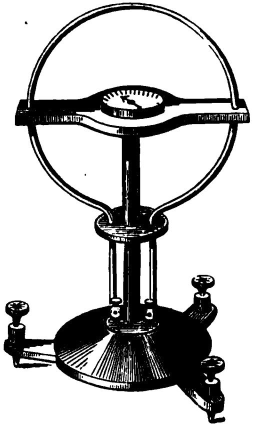


Fig. 14.—Tangent Galvanometer.

But even tangent galvanometers cannot be used to obtain measurements in absolute units until they have been compared with a standard instrument or with the results obtained from the voltameter.

The *Voltameter* usually consists of a glass vessel partly filled with acidulated water. Two small platinum plates are placed near to each other in the liquid, and are connected by wire to external binding screws. When the current to be measured is passed the water begins to decompose, and the gases, oxygen and hydrogen, are collected by means of a tube, or they may be allowed to ascend into two graduated glass tubes (Fig. 15), so that their volumes may be measured. The unit of current may be taken as that which will give off *one cubic centimètre of gas per minute.* Double the current, and the flow of gas will be doubled also. The work-power of the current is expended in the decomposition. One weber per second will decompose ·00142 grains of water. This instrument is exceedingly useful to the electro-depositor; it is low in first cost, or may easily be made by himself; it is understood with ease, set in action quickly, and when a graduated tube is provided, from which the gas may displace the water as it ascends, the trouble is reduced to a minimum. An element of error—which, however, is insignificant under ordinary circumstances—is introduced when the current is much weakened by the resistance of the voltameter.

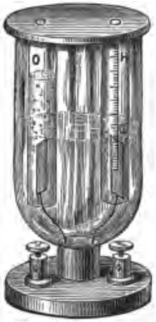


Fig. 15.—Voltameter.

The voltameter is not well suited for measuring currents from one cell only; two or more cells are usually required to decompose the acidulated water.

A small coppering cell, with plates which can be weighed, will answer every purpose, whether one or more cells be used.

Ordinary Galvanometers are simply magnetic needles, variously hung and supported, around which coils of wire are wound, leaving a chamber for the needle. The circuit, for use in electro-deposition, should offer little resistance. Ten or twelve turns of No. 16 silk-covered copper wire will usually answer very well. The length of the coil should be such as to allow the needle free motion within it. The needle should carry a pointer, moving over a graduated dial. *Equal deflections upon the same instrument always indicate equal currents;* but it must be remembered that the degrees have no real meaning in relation to units. Many of these instruments have two circuits—a long one of high resistance for weak currents, and a short one of low resistance for stronger currents. The deflection in either will, in most cases, have to be reduced, by means of a shunt-wire, to a convenient angle. *Differential* galvanometers have two equal circuits, and the two currents to be compared are passed through the instrument in opposite directions. If the currents agree the needle will not deflect, because the force tending to the right is equal to that tending to the left; but if one current should be stronger than the other, the needle would deflect to that side. It is impossible here, however, to examine the different kinds of work which may be done by means of each of these instruments. The reader is again referred to a standard text-book for more extended information. Fig. 16 represents a very sensitive galvanometer on the astatic (double needle) principle.

Sprague's Galvanometer. — Mr. J. T. Sprague patented, in the year 1869, a galvanometer capable of indicating the work-power of a current at once upon its dial; by its aid resistances may also be indicated. It is expressly constructed for the use of electro-depositors.

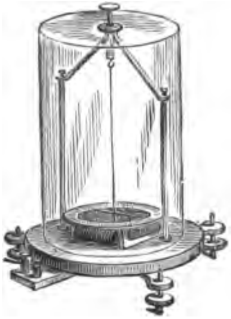


Fig. 16.—Astatic Galvanometer.

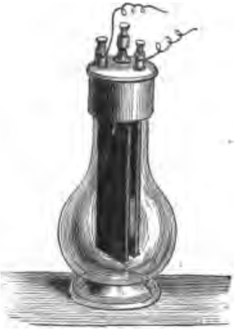


Fig. 17.—Bichromate Testing Battery.

Fig. 17 represents a small bichromate cell (p. 53), which will be found extremely useful in various tests.

Measurement of Resistance.—A few remarks on the determination of the internal resistance of batteries and of depositing solutions may not be out of place, while they may encourage the reader to more correct methods of working. It must be observed, however, that these instructions should be followed up by reference to some such work as Sprague's "Electricity" or Jenkin's "Electricity and Magnetism" for fuller information.

By Ohm's formula, when the electro-motive force and current are known, the determination of the resistance of a cell is as follows:—

$$\frac{E}{C} = R \text{ or } \frac{\text{Electro-motive force}}{\text{Current}} = \text{Resistance.}$$

The galvanometer method is, however, more generally applicable in the work of the electro-depositor. A tangent galvanometer must be used. Connect up the cell through such a (known) resistance of wire as will produce a convenient deflection; add known resistance until the current-value of the deflection is exactly halved. As the current is halved the resistance has been doubled, and deducting the external resistance gives the internal, or we may simply find the difference between the first and second added resistance, because it is equal to that of the cell. These resistances may be obtained from resistance coils, in Ohm's units. They may also be added by means of Wheatstone's rheostat, the wire of which should be graduated to read ohms. The voltameter, or a cell in which copper is deposited, may likewise be employed to measure the resistance of a circuit exactly as if it were a galvanometer, except that gas must be measured or the copper weighed.

In all such work the operator should be careful to avoid the introduction of errors, by means of leading wires too thin or other resistances not usually calculated. Voltameters for large currents may have plates about one inch square; but for small currents they should be as small as possible, graduating down to mere points. The work of dynamo-electric machines may be measured as given above; but the apparatus should be larger and less liable to injury by the current. The internal resistance of a dynamo-electric machine is seldom so great as one ohm.

The usual indicating galvanometer employed upon dynamo-electric machine circuits consists of a large needle, moving freely over a graduated half-circle. The base of the instrument is simply pressed against the leading wire from the machine; no coil is used. This forms, of course, a mere detector of the current, but it may be mentioned that equal deflections indicate equal currents, on this as on other galvanometers.

CHAPTER IV.

The Solutions.

HE who would master the art of compounding and successfully working an electro-depositing solution must ground his experience upon the fundamental principles underlying electrolysis. No great difficulty is presented here; an hour or two of intelligent study of the first chapter in this volume will be found to go a long way to clear up the mystery ordinarily presented to the electrotyper in treatises on electro-metallurgy. Hence, to pass beyond the stage of "knowledge" designated by the words "rule-of-thumb," the electrotyper should strive to gain a firm hold upon principles as far as they apply to the practice of his art. Apart from the laws of the current, which should be intelligently understood, the reader should be able to judge of the following points in the chemical and physical constitution of a solution.

It is of the first importance to know whether the solution is really an electrolyte (many solutions are not electrolytes), and whether its chemical composition will admit of the deposition of its metal in the malleable state. This even is not enough; it must also possess the power of dissolving the anode with sufficient freedom without retarding the actual current or redissolving its cathode. This simply means that it must contain a given amount of water, free alkali or acid (as the case may be); that it is sufficiently fluid to allow of free circulation; that its action upon the anode shall be just fast enough to compensate for the loss of metal deposited upon the cathode plate, and that its temperature is correct for the quality and hardness of metal required and the current employed.

Not less important is the question whether it is a good conductor of electricity; for, although this may in some cases be allowed for by regulating the electro-motive force in circuit, a solution low in conductive power is a constant source of trouble and expense; it also becomes unduly heated, and other complications arise, which render the free deposition of tough, good metal very difficult.

Of that class of solutions which do not conduct electricity (in the ordinary sense of the term) tetrachloride of tin may be cited as a good example; such solutions cannot, therefore, be called electrolytes. Nitrates in any solution render the deposition of metal almost impossible, because of the high oxidizing power of the liberated acid.

The best solutions in use are those in which sulphates and cyanides form the chief element.

They are easily made, understood, and managed, and are all good conductors.

Solutions for the deposition of copper may be made in two ways. 1. The salts may be prepared or provided and simply dissolved in the water with a percentage of sulphuric or other acid; this is known as the chemical method, although as applied to copper solution it is a mere mechanical mixing. 2. The battery may be brought into use and the salts formed in the solution from the metal by its aid. This is known as the battery method.

Each of these methods has its advantages. In the practice of the chemical method it is necessary first to prepare the ingredients, which should be fresh and free to dissolve, then to mix them in the required bulk of distilled or filtered rain water. The battery method consists in employing (say, for a copper solution) a copper plate as an anode in an acidulated mixture (water and sulphuric acid) and another plate of ordinary metal, but preferably of copper, as a cathode. A current from a cell or two is now passed in the ordinary way. In a short time a sufficient quantity of metal will be found dissolved off the anode, and when the solution is in a condition for working a deposit will appear upon the cathode. If the anode be weighed before being placed in the solution, and again after the current has dissolved off a sufficient weight of the metal, the true ratio which must exist between the amount of metal and volume of liquid will be ascertained. This is the operation of nature, and affords a most instructive lesson in the art of electro-deposition.

Copper Solution for the Single-cell Process.—A solution for the single-cell process of deposition (p. 25), suited to the coating of most metals except steel, iron, and zinc, and also well adapted for the production of small electrotypes from carbon-faced moulds, consists of a nearly saturated solution of cupric sulphate, with a small percentage (a few drops) of sulphuric acid added.

Copper Solution for the Separate Current Process.—Prepare a *saturated* solution of copper sulphate, by pouring hot water on the crystals, of nearly the bulk required; add to this, for each gallon of solution, a quart of water, and finally stir in, for each gallon of solution, four ounces of sulphuric acid. In the preparation of the solution it should be noted that by "saturated" is signified that state of the liquid when it will not dissolve any additional salt. The crystals may be dissolved in a separate vessel, and then poured into the depositing trough, or the trough may be nearly filled with warm water, and the crystals dissolved into it from a few muslin bags suspended in the liquid.

The water employed may be rain water, filtered; but in cases where there is much chance of bringing foreign metals into the liquid, such as from dust, &c., from housetops, it will be found better to use distilled water. All water used, except distilled, should be filtered, or the solution may be filtered when completed.

This solution is well adapted for most purposes of the electrotyper, and has been tested repeatedly. It will deposit well upon metals or blackleaded moulds, and will be found to dissolve the anode freely while the current is passing. Some electro-depositors use a much larger percentage of sulphuric acid, but this is seldom required, except in very cold weather. Further directions for the care of these solutions are given at p. 105.

Alkaline Copper Solution for Deposition upon Iron and Zinc.—The acid solutions are not adapted to the deposition of copper upon such metals as iron, zinc, pewter, &c., because these are attacked by, and combine with, the acid radical, as explained at p. 16. An alkaline solution, which, when not aided by the current, has no effect upon these metals, is therefore employed.

It may be made by the battery process as follows:—Dissolve six ounces of good quality cyanide of potassium in a gallon of water, place this in the depositing vessel, and pass a current from a cell or two by means of a thick anode and a cathode or receiving plate of iron—in short, work the solution as in depositing until a coating of copper appears upon the cathode. The action at work is really the slow dissolution of the copper anode by the aid of the current, and its transformation into cyanide of copper. It will be obvious, however, that, as this process leaves the potash of the combined cyanide in the liquid, it is not so well adapted to work which should conduct very freely. The potash at least does no good.

It is better to make up the solution chemically by preparing the necessary quantity of cyanide of copper as follows:—Prepare a solution of copper sulphate, and also one of cyanide of potassium; add the latter to the former, when a copious deposit of copper cyanide will take place. The liquid should be poured off and the residue washed, when it may be finally dissolved in a fresh solution of cyanide of potassium (two pounds to the gallon) to form the depositing liquid. As the cyanide of copper is not freely soluble in the potassium cyanide, it should be dissolved to saturation. Free cyanide should be afterwards added to the extent of two ounces per gallon. This will promote rapid working, but there is also a stronger tendency to give off hydrogen at the cathode, the deposit in which may contain large quantities of the gas.

This solution works best when at a temperature of about 100° F., but a strong current will throw down its metal at 80° F.

Roseleur recommends a solution made as follows:—Reduce 20 parts of acetate of copper to powder, and rub it to a paste with a little water; add to it 200 parts of water containing 20 parts of dissolved washing soda, and stir the mixture; a light green precipitate is formed; 20 parts of bisulphate of sodium are now dissolved in 200 parts of water, and the solution mixed with the former one; the precipitate becomes dirty yellow. And, finally, dissolve 20 parts of perfectly pure cyanide of potassium in 600 of water, and add it to the previous mixture. If the solution is not quite colourless, add more cyanide until it is so. This liquid may be used either hot or cold, and requires a current of moderate strength.

Management of the Solutions.—It is sometimes very erroneously supposed that a solution, when it goes into work, changes and becomes weak, whereas the very essence of part of the electro-depositor's skill lies in his ability to keep the solution as nearly in its original condition as possible. Having once secured a really good solution, by following out any of the foregoing sets of instructions, the great object should be to *keep* it good. The solution may be looked upon as merely the dissolving medium in the operation of depositing; it should not give up a particle of its strength to the deposit, its true work being to carry the metal from anode to cathode. If it does this to perfection, the anode will be found to dissolve just as fast as the metal is deposited on the cathode; if the solution should dissolve the anode too fast, its free acid or alkali will be absorbed; and, although this fault carries to a certain extent its own remedy, inasmuch as the acid can be recovered by working with a smaller surface of anode, the conductivity of the liquid will be impaired, and the deposition rendered sluggish.

On the other hand, should the anode be dissolved too slowly, that is, not fast enough to make up for the metal deposited, the electrolyte must naturally become weak and useless by the abstraction of its metal. This fault may, to a certain extent, be overcome by the addition of free acid or alkali (as the case may be) to cause the anode to dissolve more freely.

The range within which good copper may be obtained is, however, sufficiently wide to allow of reguline deposits being obtained from greatly different solutions. Sulphate of copper solutions are usually very easily managed. In this respect they are superior to any other solutions used in the whole range of electro-metallurgy. This means that the current may be varied to a considerable extent without causing the deposit to exhibit defects. But although this is strictly true, it is none the less obvious that the working speed can only attain a maximum where solution and current are regulated to work together in mutual relationship in accordance with the laws expressed at p. 21. Quality of metal and speed of working are the two great aims of the electrotyper. Some depositors work twice as fast as others, and yet obtain the toughest and best copper in their electrotypes; but the latter class of manipulators either work from the teachings of long experience, or, better still, from a clear knowledge of the principles upon which their art is based.

Allowing the strength of the current to be correct, the required deposit cannot be drawn from the solution because of the following defects. If the solution be too dense, by reason of too great a percentage of copper, the deposit obtained will be tardy in forming, and exhibit, in most cases, a crystalline structure; at best it will be brittle and liable to break away. If the liquid should be poor in metal, the deposit is apt to have the opposite defect—a porous structure, quickly deposited.

These faults may likewise be caused by the variations of *temperature* to which the solution is usually subject. So great is the effect of raising or lowering the working temperature that a difference of five degrees frequently seriously affects the speed of working and the quality of the metal secured.

Care should, however, be taken to insure that the anode and cathode have surfaces nearly equal to each other, or at least that the anode shall be the larger. If the anode be too small the deposit is apt to be brittle, and the rate of deposition will be seriously affected.

If the current be too great in proportion to the amount of the receiving surface and the strength of solution, the deposit will prove spongy or coarsely granular. If the current be weak, the opposite defect of brittleness may exhibit itself. The current, however, within limits widely apart ordinarily affects the *rate* of deposition only.

Streaks on the back of the electrotype indicate that the liquid is too dense, and contains too much copper for the volume of water. A heavy deposit at the lower end of the cathode and a thin one at the top indicate the same defect. The cause of the latter fault is as follows:—When the solution becomes overcharged with metal, its heavier portions settle at the bottom of the vessel, while the lighter acidulated water, or weak solution, occupies the upper portion of the vat. The consequence is that the current plays most favourably through that portion or stratum which conducts best, or answers its strength, or it may act almost equally upon the cathode, and yet deposit different weights on different portions of its face. When this defect exists for some time, it will be observed that the deposit upon the upper portion of the cathode frequently becomes dissolved, and that crystals of copper-sulphate form upon the plates and bottom of the vessel. This usually indicates a deficiency of water, and also the want of stirring.

The temperature of the solution should indicate as nearly as convenient 60° F., and this should be preserved in winter and summer. If the temperature cannot be kept up to this, the battery power must be increased to obtain the ordinary quality and metal at the usual rate, or *vice versâ*. Further guidance on many of these points will be found included in the instructions for depositing in Chapter VIII., p. 189.

No experiments should be made with the solution, as the whole is thus apt to be rendered useless for working. A small quantity of caustic soda will increase the rate of working; but its use is not to be recommended, as the same rate can be obtained by proper attention to the current and size of anode.

The electric current should always be adapted to the liquid, not the reverse. How to determine the necessary strength of current may be learned from a careful perusal of the instructions on p. 186.

Quality of the Solution.—It should have no tendency to decompose its own deposit; it should not be affected by the atmosphere, or by the action of light; it should dissolve the anode freely, and should yield a reguline metal with moderate battery power at 60° F.

Test for New Solutions.—Before a new solution (one not known to the operator) is tried upon a large scale it is wise to first test it for several defects as follows:—Place a quart of the mixture in a stoneware vessel at 60° F. Employ an anode of clean copper one inch square, and a cathode of similar size; weigh these before passing the current. The cathode should be of blackleaded gutta-percha, if this is the moulding material to be constantly used. Pass the current from two Smee or Daniell cells, with two inches or more of space between anode and cathode. Observe, first, whether the current evolves gas at the plates. If a little gas appears, it may be stopped by slightly separating the plates; but if much gas comes off, especially from the anode, there is a defect in the solution, and the current would be wasted upon thus decomposing it. Test the speed of deposition by weighing the plates; the anode should lose about as much as the cathode gains. Test the toughness of the deposit by bending it and hammering.

The liquid should further be tested by exposing it to the air and light for some days, and observing whether it shows a sediment or begins to decompose.

Reversal of Current in the Solution.—This peculiar counter-current is particularly to be avoided where dynamo-electric machines are used, and sometimes under ordinary conditions; it may be observed as follows:—Deposit a layer upon the cathode, and weigh it (the cathode); place the cathode in the bath again and disconnect the battery, but connect the cathode and anode by a wire. A counter-current, passing from the cathode to the anode, will be set up in most cases, and the cathode will lose metal while the anode will gain an equivalent amount. This may go on for a few minutes, when another reversal may take place. In the case of employing a dynamo-electric machine as the source of current, the effect is generally to reverse the polarity of the machine, which upon again being set in motion will give a current in the wrong direction. Some machines have circuit-breakers to open the circuit when they are stopped, to meet this defect. (See also p. 84.)

Iron-facing Solutions.—A good solution for the deposition of iron in "steel-facing" electrotypes may be made as follows:—To each gallon of water dissolve one pound of carbonate of ammonium, and dissolve iron into the solution by passing a strong current from an anode of iron until a deposit appears upon a clean copper cathode. A few ounces of carbonate of ammonium should be stirred into the bath about once a week. The anode, which should be large in proportion to the work, must be cleaned occasionally.

The solution most in use for the "steel-facing" of printing plates is prepared as follows:—Prepare a solution of sulphate of iron, and another of carbonate of ammonium. Add the latter to the former until the iron is precipitated; pour off the liquid portion, and wash the precipitate. Take a bulk of sulphuric acid equal to the volume of solution required, and dissolve the iron precipitate in it *to saturation*. If there should be any free acid it will retard the working; it is therefore usual to evaporate the solution a little.

From either of these solutions good iron may be obtained by the current of three or four Smee or Daniell cells, but a stronger current is usually employed for quickness of working. The anode is always of iron, and the cathode of copper. The anode is usually from five to eight times *larger* than the cathode, to prevent the solution from becoming acid. It is also advisable to leave the anode in solution when not in use, and to connect it by a wire to a cathode of platinum or copper to prevent the formation of acid, and to keep the bath as dense as possible. The metal obtained is usually as hard as good steel, but becomes soft and malleable after heating. It is highly important to have a solution which yields a crystalline and very hard coating of iron.

A coating obtained from a solution of sulphate of iron and chloride of ammonium yields an exceedingly hard deposit of the purest iron, and it is thus well suited to the coating of small and very fine electrotypes of steel engraved plates. Plates coated in this solution have been known to yield as many as 10,000 impressions in printing, all sharp.

All solutions made from sulphate of iron simply are very troublesome, and are constantly acted upon by the air, thus spoiling the solution. The salts in these solutions pass to a higher state of oxidation by absorption.

Management of the Iron Solution.—All iron solutions should be kept as much as possible from the air, owing to their tendency to absorb oxygen and pass into persalts. It is believed that the oxygen which is frequently set free at the cathode may be absorbed by the deposit, which is thus apt to be porous when of any considerable thickness. When a solution has become spoiled by the action of the air, it may be deoxidized by passing a constant current for many hours from an iron anode to a copper cathode. Some electrotypers add a little glycerine to the solution to aid in its preservation. Some solutions constantly deposit a slimy layer of impurities upon the anode, which must be kept clean.

A layer of solid paraffin may with advantage be melted over the surface of small bulks of iron solution. This has the effect of screening them from the air to a great extent; but it is only applicable in cases where the anode and cathode are always placed in the same position.

Iron deposited from solutions in which glycerine has been dissolved is apt to begin to crack when a moderate thickness is attained, but this never takes place within the thickness required for the facing of electrotypes, except the glycerine be present in excess.

Inexperienced workers usually deposit defective iron with numerous holes. This is almost always due to too great a percentage of free acid and too strong a current. Acidity should frequently be tested for with blue litmus-paper.

When thick deposits are required from a solution the battery power must be comparatively weak, or they are apt to contain large volumes of hydrogen.

Iron solutions should be added to when iron is required from an anode of iron as pure as possible. Cast iron should never be employed. Charcoal iron is the best; failing that, wrought plates may be used. Acid and ammonium carbonate or chloride (as the case may be) may have to be added occasionally to make up for the oxidized salts, but much care is necessary not to materially change the composition of the bath. The solution works faster and conducts more freely if slightly heated. (See also Chapter IX.)

Nickel Solution.—In many respects solutions for the deposition of nickel are similar to iron solutions, and the process itself is almost the same.

The nickel solution is generally made from the salts direct, but as these are not always procurable at a fair price it may be made by the battery process, or the salts may be formed from common grain nickel direct, as follows:—Select a deep glazed vessel, into which pour three parts of strong nitric acid, one part of strong sulphuric acid, and four parts of water, all by measure; mix with a glass rod. To each gallon add two pounds of commercial grain nickel, and heat the mixture by placing the vessel in boiling water. Care should be taken to avoid the fumes given off. If the action should become violent add a little cold water, or moderate the external heat. Stir occasionally until all the nickel is dissolved. If the liquid will dissolve more, add it until the solution is saturated with nickel. When fully prepared, the solution gives over fuming and feels heavy and dense. Stir in one-fourth its bulk of hot water, boil it, and finally filter. This is a strong solution of the sulphate of nickel. Dissolve next sulphate of ammonia in hot water until saturated, about four pounds to the gallon; prepare a volume corresponding with that of the previous solution. Allow to cool, and add the ammonia solution to the nickel one with agitation until the latter loses its colour. A precipitate of the double sulphate of nickel and ammonia will take place. Decant the liquid portion, and wash the resulting double salt with a little cold ammonia solution.

The depositing solution may also be prepared from the double salt as obtained in commerce. In either case dissolve the compound in hot water to saturation; afterwards dilute with water until a Twaddle hydrometer indicates a density of seven degrees; or simply dissolve three-fourths of a pound to each gallon of water. The solution should be neutral, or nearly so; that is, neither acid nor alkaline. To ascertain this, test it with blue litmus-paper; if the paper be turned red, increase the alkali by adding ammonia sulphate. If red paper be turned blue, increase the acid by adding nickel sulphate until the mixture is as nearly as possible neutral. If there should be a tendency to either side in working, it is better to have it rather alkaline. Anodes for this solution should be of nickel plate (cast), which may be procured in commerce; they should be larger than the cathodes. Particulars for working are given in Chapter IX.

Brass-Facing Solutions.—Although it is to a certain extent true that the current exerts a kind of selective influence upon the metals that chance to be present in an electrolyte, it is a great mistake to suppose that metals deposited by electricity must necessarily be pure. When an alloy is in solution, a weak current will select and throw down the one most easily separated, but when there is a sufficiency of force both metals are deposited without regard to their nature. Hence brass, an alloy usually of seventy-one parts copper to twenty-nine parts zinc, may be deposited by electricity, and forms an excellent protective facing to copper printing plates, although it is in this respect inferior to iron. Its most obvious advantage would appear to be that brass is found to take and print colours, the vermilion in some varieties of which destroys the copper face by combining with it. But the most extensive application of brass facing is in relation to bookbinders' tools and such stamps as are frequently heated.

A good solution for the deposition of brass of a hard nature may be made as follows :—Dissolve in one thousand parts of water twenty-five of copper sulphate and twenty-five to thirty of sulphate of zinc ; or twelve and a half of acetate of copper and twelve and a half to fifteen of fused chloride of zinc. Precipitate the mixture by means of one hundred parts of carbonate of sodium dissolved in plenty of water, and stir the mixture. Wash the precipitate several times by adding water to it, stirring, and allowing the precipitate to subside, pouring the clear liquid away. Add to the washed precipitate a solution composed of fifty parts of bisulphite of sodium and one hundred of carbonate of sodium dissolved in one thousand of water, and, whilst stirring, add a strong solution of ordinary cyanide of potassium until the precipitate is just all redissolved, then add three parts of free cyanide. This solution is used warm or hot. (Roseleur.)

A current from five to six Bunsen cells in full force should be passed into the bath. The anode should be of brass. When the deposit is white it is usually caused by too strong a current, and when red the current is probably too weak.

CHAPTER V.

Depositing and Moulding Apparatus.

THE apparatus to be described in this chapter consists of the depositing or solution vessels and all their furniture, including conducting-rods between the electric source and the vessels; also moulding apparatus, used in taking the matrix from all kinds of flat-surface work, and devices for obtaining the pressure required in forcing the work and mould together. These include the chief pieces of apparatus employed in electro-typing, excepting the source of electricity, which receives special notice in Chapter III.

Depositing Vessels for Small Operations.—The depositing vessel employed in obtaining electrotype copies of such small objects as medals, or any object up to three inches in diameter, is in most cases the containing pot of a Daniell cell (p. 25), the zinc and porous diaphragm of which also serve as a source of electricity. This is known as the single-cell depositing apparatus; it is slow in work, but gives little trouble, and can be made to deposit the finest possible electrotypes. The process itself is described at p. 26 and p. 180. But small operations which are required to be accomplished quickly, so as to obtain a good strong electrotype in about ten hours, should be conducted entirely in a separate depositing vessel. Its size must be in proportion to the magnitude of the work, but it is always well to err on the side of having too large a depositing vessel. Square and oblong troughs of brown glazed earthenware are obtainable now at philosophical instrument shops in all ordinary sizes. One 12 by 8 by 6 inches will prove an excellent trough for all small operations. This shape of vessel is more convenient than a cylindrical cell. The same vessel may be made from good teak well jointed and thoroughly coated two or three times within with marine glue or gutta-percha (p. 148). Wood may prove more troublesome at first, but it offers a convenient means of fastening anode and cathode, conducting-rods, and terminals to the trough. A very convenient and easily fitted set of connections may be placed upon a vessel of this description as follows: —Mark off the half of the length upon the upper edges of the trough, bend (angular) two pieces of $\frac{3}{8}$-inch copper or brass tubing to extend along each end and both sides of the trough. They should be made of a U shape, but with angular bends; the length of the legs should allow the two pieces, when laid upon the edge of the vessel, to nearly meet at the central line marked off. They should be screwed in position with three screws each, and a wire clamp or terminal (p. 56) should be soldered to each at one side of the trough where the rods nearly meet. The anode and cathode rods, consisting of straight pieces of tubing of the same size, two inches or so wider than the trough, may be conveniently laid across their respective ends and approached or separated as required. Fig. 18 exhibits the depositing vessel complete.

In order to keep the top edge and connections of the vessel dry, which is a matter of some importance, to prevent leakage of electricity from one end to the other, a ledge of wood may be arranged to rise from the inside of the trough nearly to the height of the tubing. The cost of such a vessel, made soundly of teak, and fitted as described, should not exceed five shillings. It is adapted for the production of electrotypes up to 3 inches in diameter, so that all kinds of small woodcuts can be copied in it, up to 3 inches wide by about 5 inches long. The anodes for such a depositing vessel should be of ¼-inch copper plates, 5 by 3 inches, provided with a pair of soldered stout copper hooks, to sling upon the anode rod and allow the plate to reach within 1 inch of the bottom. Two smaller anodes, for small work,

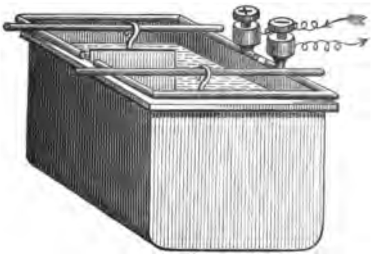


Fig. 18.—Small Electro-typing Vat.

should also be at hand, because the cathode and anode should nearly agree in size; these may be 3 by 2½ inches and 2 by 1 inch respectively. This completes the apparatus ready for receiving the solution (p. 102) and commencing electro-deposition. The same vessel may be employed for the deposition of any other metal, such as silver or iron. In such cases the anode must be of the metal to be deposited. When in use it will be found advantageous to siphon off the solution after each electrotype has been deposited, and to clean out the vessel of anode sediment. The solution may also be strengthened, should it be required, before being replaced. After a time the rods will become oxidized and retard the passage of the current. To prevent this emery cloth should be used to brighten them before putting into use. The binding screws should likewise be kept clean, and must clamp the battery wires securely. The battery should always be placed behind the trough, so that the front of the latter may be free for inspecting purposes. With such a depositing vessel, a pair of Smee, Daniell, or bichromate cells of two-quart size will form a battery of ample strength. (See p. 21.) They may both be used, joined for electro-motive force, in driving a deposit over a blackleaded matrix; but one will prove sufficient when the surface has been covered. A 3-inch electrotype of a wood-block may be taken out in about twelve to twenty hours. (See *Depositing Process*, p. 182.)

Depositing Vessels for the Larger Operations.—The dimensions of vats for ordinary large work vary; a good size for a printer's electrotyper is 5 × 3 × 3 ft., and larger or smaller in proportion for large or small art-work. From 100 to 300 gallons of solution may be worked by the battery or dynamo-electric machine.

The choice of material should be made from wrought iron (boiler-plate) or wood lined with sheet lead. The best possible vat is one made from moderately stout boiler-plate *enamelled* within; such a vessel possesses all the advantages of a porcelain one with the strength of an iron one. A vat of boiler-plate, made tight and afterwards carefully painted within, while warm, with marine glue (p. 148), serves the purpose very well, and gives no trouble. Wooden vats, made from good seasoned teak well jointed, and afterwards secured with rods and nuts, may be employed if well painted with the marine glue mentioned above. But they are neither so satisfactory in use or cheap in the end as iron vats. A wooden vat, properly lined with sheet lead, put in with burned joints, answers perfectly; but it is frequently as expensive as an iron one.

Many other materials are in use as linings for wooden vats. Gutta-percha is common, but it perishes in time. Plate-glass is frequently employed, bedded in cement, but it is at first expensive, and apt to be broken by articles falling into the vat. Slate is better, and is often used. Asphaltum is frequently employed as a lining, and stands for some years if well applied at first. In the case of lining a wooden vat, it must be new and *perfectly* dry. The necessity for this condition prevents the possibility of thoroughly coating a vat for the second time; hence the advantage of a carefully enamelled iron vat, which in good hands should last fifty years or more. Any accidental chipping of the enamel should be carefully covered with marine glue applied hot to the heated part. Pinholes of the larger size should be treated in the same manner. Care should be taken, in first fixing the vat, that it shall have a seating as equal as possible; that is, the vat should not be so placed that when the heavy solution is poured in, it may be twisted, so as to chip off the enamel.

For dynamo-electric machine working the vat should always be *deeper* than for battery work. This will prove all the more necessary when a circulator of the solution (p. 191) is employed. One foot extra is usually enough. In deciding upon a depositing vat, it should always be remembered that a large bulk of solution works in every way more satisfactorily than a small bulk. It gives a more uniform deposit in less time; the component parts of the whole are not so easily disturbed by accidents; it dissolves the anodes more regularly than a small bulk of solution, and is in every way better adapted for rapid and good working.

A vat to work surfaces not larger than two

4to matrix frames together should not contain *less* than 150 gallons of solution. There is no economy in working a small vat where a larger one can be used. It is found cheaper to work a 600-gallon vat than a 200-gallon one, even although the work be small enough to deposit in the lesser vat. Hence the solution *should* always be greatly in excess of what is absolutely required; and to some extent the same may be said of the current; it should be rather in excess of what will do the work, because it always proves troublesome to be rather *short* of battery power, and to find that the difference of an inch or two further from the anode reduces the speed of working to one-half.

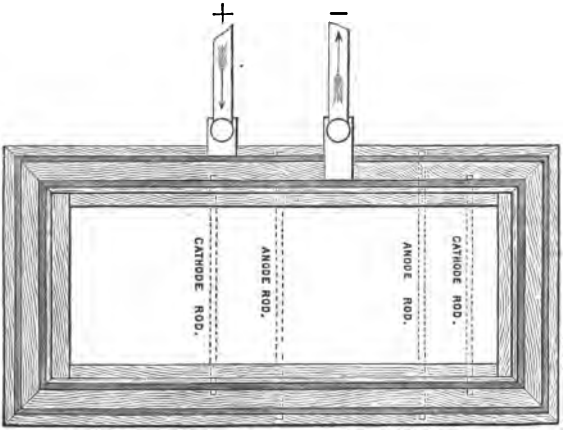


Fig. 19.—Plan of large Electro-typing Vat.

It is quite probable, indeed, that a 50-gallon vat of solution will, with a small battery, cost 20 per cent. more in working expenses than a 400-gallon vat. Small bulks of solution often give trouble, but it is seldom that a large body needs renewal within five years of its establishment.

Conducting Fittings for Large Vats.—The chief difference between the furniture of a small and a large depositing vessel arises from the fact that in the latter work of two sides must frequently be done, and two or more anodes must in consequence surround the article. The fittings mentioned in connection with the small vessel are arranged specially for flat work, or work which might be deposited upon one side at a time: but in larger operations we have frequently to deal with cases where several pieces of flat work to be done at once necessitate the use of conducting-rods representing *both* poles at *each* end of the vat (Fig. 19.)

The vat, whether it be of wood or iron, should be provided with a ledging of wood, about 3 inches wide, extending around its upper edge. The outer edge of this ledge should be half an inch higher than the rest, and extending along the surface of this should be fitted a rectangle of ½-inch copper or brass tubing, raised if possible from the rim by means of studs at the corners and centres of sides. Another similar rectangle of tubing should be fitted to run round the inner portion of the wooden ledge. It also should be raised slightly from the wood in case of conduction taking place between the rectangles by damp or accidental spilling of solution on the ledge. A strong wire binding-screw should be soldered to each rectangle, to take the wires from the battery or machine. The outer rectangle should always represent the positive pole, and the inner one the negative. It will thus be observed that a vat so fitted can take in anodes or cathodes *at any part of the solution.* Stout copper (inch tubing) rods, according to the number of anodes, extend across the *positive* rectangle, so that they may be moved to any required part of the vat. Similar rods, short enough to move *within* the raised ledging above referred to, extend from one side to the other of the *negative* rectangle. If there should be any risk of the positive rods being displaced, they may be bent down at the ends to clutch the rod from the outside, and yet be free to move from end to end of the vat. Should the negative rods be apt to touch the positive rectangle, they should be fitted with plugs of wood, slightly projecting at the ends, or caps of gutta-percha; but a separating slip of wood is more satisfactory.

All these arrangements, when completed, should be well painted with black varnish, except the upper surfaces of the rectangles, which must be kept clean. No solution should be spilled upon these conducting arrangements. From one to fifty anode rods and an equal number of cathode rods may thus be at work in one vat at a time, there being no tendency to confusion or risk of conduction, except through the solution. It is advisable in most cases to have a means by which the rods may be fixed in one position when the work is once adjusted as to distance from the anode. Several simple devices may be employed for this purpose. The anode rods may, as they are turned down at right angles at the extremities, be fitted at one end with a set-screw, to jam hard against the positive rectangle. One or a pair of circular, or nearly circular "grips" may be fitted to each cathode rod to grasp the negative rectangle *nearly* around the lower half, avoiding the fastenings; the cathode rods may thus be conveniently fitted each with a set-screw to jam against the rectangle at the point required. These means are very simple and present great advantages over the old plan of laying the rods across the vat in notches cut in the wood, or in semicircular holders made fast to the conducting rectangles. In the first plan the adjustment may be regulated to a nicety; in the old method it must be arranged to suit the notches and supports.

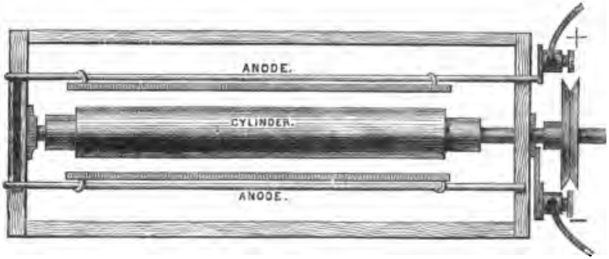


Fig. 20.—Calico-printing Cylinder Coppering Vat.

Fig. 20 exhibits a plan of the vat as arranged for coppering iron cylinders for calico and other printing purposes. It will be observed that the cylinder while it is being coppered is *slowly* revolved between two curved anodes, so that the deposit may be evenly distributed. Both anode rods are connected together to the left of the plan given; the battery or machine connections are attached to the anode rod and cylinder bearing-blocks. These bearing-blocks are arranged by means of a stuffing-box so as to prevent the escape of solution from the vessel. The cylinder itself should be at least one foot under the surface. The rotating arrang ement must be made to allow of convenient and rapid disconnection when placing or removing the cylinder.

Resistance Scales.—Upon the rectangles of well-arranged vats of this description *scales of approximate resistances* can be marked. Thus, the resistance of a certain length of the solution having been determined, it may be marked in ohms upon the rectangles, as the whole vat will present resistance in direct ratio to this. It is assumed, of course, that the volume of solution and its density are to be kept as regular to a fixed standard as possible, so that the units marked off may hold good at all times. This method was first used by the author; it enables the electrotyper to fix upon his resistance, working either from experience or calculation, at once before placing in the work, and he may thus, to a great extent, *rely upon the deposit being good and rapidly formed.* In flat work, this method is a great aid and saving of time if once put into use. (See *Resistance*, p. 96.)

Conducting Wires and Bands.—This subject is treated more fully at p. 54. The conductors from batteries are generally wires, which should be of the No. 10 gauge. Straps of copper are generally used for dynamo-electric machines, but they offer no points of advantage over cylindrical conductors, unless it be that they are more easily bent. All conductors employed should be much stouter than is actually necessary, so that their resistance may be counted as nothing. When the conductors are long, such as from a distant battery, or a machine driven by a neighbour's engine, they should be stouter in proportion, or even duplicated. Much care should be taken to fix the conductors cleanly into the binding screws at the electric source and at the vat itself. Conductors should always be led to the vat, so that they may not in any way interfere with the movements of workmen, and should be insulated with paraffined cotton or tarred twine.

Vessels for Alkaline Solutions.—Cyanide of copper solutions are in most cases used hot, hence it is generally necessary to employ an iron vat when cyanide solutions are used in obtaining first coatings upon zinc or tin matrices, or in obtaining negative electrotypes direct from articles made of metals which of themselves set up electric action in or decompose the ordinary sulphate solution. Enamelled iron vats, fitted with feet and gas jets to obtain the necessary heat, are best suited for this work. They may be of small size, as the object is merely to obtain a *preliminary coating*, the *main* deposit being afterwards obtained in the sulphate solution.

When steam-heat is available, the vat should be fitted, if an iron one, with a metallic jacket, and the steam allowed to circulate around it.

Vessels for Iron Solutions.—These are usually only a little larger than the work to be deposited upon, because the process is short, and the larger the surface exposed to the air the faster the solution will deteriorate in working quality. They should be deeper than ordinary depositing vessels for the above reason, and should contain a large volume of the solution. Iron solutions may be protected from the effects of the air, when out of use for some considerable time, by heating and melting a thin cake of paraffin over the surface, or a little glycerine may be mixed with the solution when in work. The vat may be of lined wood, or of iron, naked or enamelled.

Anode Plates.—For all copper solutions the anode consists of a plate of good copper; there is more reason than would at first appear for employing the purest copper, because the common qualities give off a great deal of foreign matter known as "dirt." Indeed, some of the first electrotypers and best workmen use in their operations only electrotyped copper for anode purposes. There can be no doubt that this plan has many advantages, more especially in work where a trace of slime or dirt is apt to ruin a whole month's labour.

Electrotyped copper is usually so pure that no trace of dirt can be found on the anodes. The plan adopted generally is to use the cylinders of Daniell cells, which have been thickly coated on both sides with electro-deposited copper. These cylinders can readily be spread out to form the flat anodes required; if liable to crack they should first be annealed. In many cases, however, the anodes are specially prepared in a separate vat, large square sheets of thin copper being deposited upon until about one-third of an inch in thickness has been attained. For ordinary rough electrotyping this method is not necessary. Electrotyped copper cannot be said to be much dearer than the common qualities, when deposited by the machine, because it is *all* copper, and can be weighed, pound for pound, to form electrotypes. Common sheets frequently contain 25 per cent. of useless matter, which at best cannot be called good copper. The thickness of anode copper plate is usually one-third of an inch, but any thickness may, of course, be employed. It is found that anodes heated and plunged in water become softer, and yield better under the influence of moderate currents. (For *iron* anodes, see p. 113.)

Size of Copper Anode Plates.—The anode and cathode should each present an equal surface to the solution. The anode has two sides, but the back, when facing flat work, should be left out of account. Hence, an electrotype a foot square should be faced by an anode a foot square. If there be any difference in size, the anode should be the larger. When the solution is found to be, from any accidental cause, weak in metal, the anode should be the larger to make up the deficiency. If the solution be too dense, the anode should be slightly smaller than the cathode, which will thus take up the excess. When the anodes are of inferior quality, and much dirt is given off, they should be larger than the cathode, otherwise the solution will begin to lose metal.

Shape of Anodes.—This is a matter of the greatest importance, but as it properly belongs to the depositing process, it cannot receive full treatment here, except with special regard to general requirements.

All work level over the face of the matrix should have flat anodes. All work curved convex should be faced by concave anodes, and all work curved concave by convex anodes. This resolves itself into the simple statement that *the anode must be parallel to the cathode.* The distribution of anode power is effected, on undercut surfaces, much more evenly by working with the anode at a considerable distance. Taking, as an example, a flat cathode surface, with a depression in the centre, an attempt to obtain a copper deposit over both depression and surface with the anode in close proximity would probably fail, but would be easily accomplished if the anode were removed to a greater distance. Hence, the discrepancy between the coatings received by hollows and prominences is always more marked when the anode is near than when it is placed farther away.

Chases.—These are shallow dishes of iron or backing metal, used as frames or trays, in which the moulding composition is poured previous to pressing the face upon the composition. They are generally about $\frac{1}{3}$ of an inch deep, and the usual sizes are from 2 inches by 3 inches to 10 inches by 13 inches. One of the ends is extended, and pierced with two holes, in which the vat hooks may be fastened. It will be observed that this arrangement, as it is merely a metallic tray, must be varnished all over the back and sides to prevent the deposit from spreading uselessly upon these parts. Simple arrangements may, however, be adopted, which effectually cut the main frame out of the circuit. Thus an iron tray as above, of the required depth, is fitted with a narrow copper frame, which is insulated from the tray by four angle pieces of ebonite. The narrow frame fits tightly to the tray, and is provided with the required extending loops for connection to the negative rod of the vat. When the wax is poured into the tray, it reaches the conducting frame all round. When the mould is blackleaded, the conducting surface includes the narrow frame edges, but not the back of the tray. In this way "stopping off" the tray is rendered unnecessary. When the moulding composition is of itself conductive, however, as it frequently is by the addition of powdered plumbago, this plan does not of itself answer. The narrow frame must in this case be a tray also, to fit inside the larger one; and to prevent its back from coming into electrical contact with the main tray, the latter is fitted with a thin lining of ebonite in addition to the ebonite insulating corner-pieces already mentioned, or a few coats of hard Japan may be baked upon a tray of the common kind. In Chapter VII. are given particulars of a new system of medallion trays.

Moulding Composition Vessels. — Most of the moulding compositions now used are made up by the aid of heat. The greater number, being compounds of wax, gutta-percha, and such substances, are melted and kept liquid in an iron pot by means of a jet or two of gas. Where steam is available it should be used to heat the pot, by being passed through an outer casing surrounding its bottom and sides; by this means a more uniform heat is secured. Sheet-iron wax vessels of 12 inches by 9 inches are most convenient when steam is employed as a source of heat, but when gas is used they should be thicker in body, or ordinary cast-iron pots.

Pressure Apparatus.—When the tray is carefully filled with the moulding composition (in flat work), the prepared original is placed upon its surface, and great pressure is applied to secure an accurate copy. For small operations, makeshifts are frequently employed, such as copying presses or even vices; sometimes amateurs employ a device consisting of a wood beam, jointed at one end near the floor to a post or wall, and by placing the work under it near to the fulcrum, a good pressure is attained by sitting upon the free end. These makeshifts answer well enough for the smaller kinds of work apart from regular electrotypers' operations, but in the moulding of set-up types and blocks they are troublesome and often useless. Large screw presses are common, but the best presses are actuated through a pair of toggle joints, and are therefore known as toggle presses; they are extensively employed by electrotypers, as they are lower in first cost than regular hydraulic presses. The hydraulic press is employed for all kinds of flat work, large and small. By its aid a great pressure may be given by the expenditure of little tiresome energy. Each press should be fitted with a sliding platen, to admit of proper adjustment of moulds before applying the pressure. Further information regarding the pressure apparatus will be found at p. 164.

Blackleading Brushes.—When a mould or copy is secured, by pressure or otherwise, the non-conducting surface must be prepared with a view to render it conductive in the solution. In most cases blacklead, as it is popularly styled, is used. It is generally applied to the matrix dry, in the form of a fine powder, by means of soft brushes. These brushes may be of camel-hair, cut short and stiff, or, for ordinary work, of goat's-hair. A round brush, about two inches in diameter, is well adapted for most work to be blackleaded by hand. The operation itself is described at p. 166.

Blackleading Machine.—Machines for the purpose of applying the plumbago surface to moulds (flat work) are now extensively used, especially in America. The operation of the machine presents some advantages over hand-work, because it is more rapid and less wasteful of blacklead.

The machine consists of a raised table, perforated with numerous square apertures. Under the table is fitted an inclined box, in which all waste blacklead is caught. The table is connected within a frame with a screw and pinion, which give it a reciprocating sliding motion under a wide, soft brush, which, being also connected to the gearing, receives a vibrating up and down motion at great speed. When the mould, plentifully sprinkled with finest blacklead, is placed upon the sliding-table, and the machine set in motion (by the hand), it is carried beneath the face of the vibrating brush, back and forth, receiving the beating-in effects of the brush until the whole surface is rendered uniformly conductive. The machine when in operation is usually covered with a top case to prevent waste of blacklead. It is almost needless to observe that these machines are only properly adapted for flat surfaces; their use, indeed, is chiefly confined to the practice of the printers' electrotyper. They cannot be said to be well adapted to the production of the best class of conducting surfaces, or to the finest kinds of electrotype moulds, unless the latter be of a material at least as hard as cold gutta-percha. Machines are adapted to all the usual requirements of printers' electrotypes, and in this, their proper sphere, save expense and time. They may be rotated by hand or power.

"*Slings*" *and Hooks.*—These are bright copper hooks and catches used in hanging the cathode (mould) from the negative rod of the depositing vessel in the solution. They should be made of copper wire, which may be gilt, of about No. 10 size. The same kind of hooks may be used in slinging the anodes from the positive bar.

Tinning-Trays.—When the depositing is completed, and the "shell" or electrotype is removed from its matrix, it is "trimmed" and placed upon a metal tray provided with high handles, and the whole is finally floated in a bath of molten "backing metal," to be heated, tinned, and "backed." The process is detailed at p. 213. Tinning-trays may be of any convenient size; the usual dimensions admit of their receiving a pair of 4to electrotypes. They are of iron, cast or sheet; but sheet iron should only be employed for small operations, because it is liable to warp or twist. Planed cast-iron trays, with high handles of wood, are best adapted to the work. When the electrotypes are large the trays are lifted into the backing-bath by means of a small adjustable overhead crane.

The Backing-bath.—This consists of an iron tank, frequently 2 by 2 by 1 foot, nearly filled with the metal kept in a molten state. The heat is employed in tinning the back of the electrotypes and the metal in forming the backs. Gas or coal may be employed in keeping the bath at the required heat. A *firm* and *level* ledging of some solid substance should be provided around three sides of the bath ; it should be about 2 feet wide, or according to the size of the tank; its use is to receive the backing-trays before and after the operation.

Circular Saw.—This is brought into requisition in cutting away superfluous edges of electrotypes and backing metal. It may be from 2 to 8 inches in diameter, according to the magnitude of the operations, and must in all cases have fine well-cut teeth. These saws are driven upon spindles by foot, hand, or power. They are frequently mounted in a lathe, and should always revolve at high speed. A gauge-plate should be provided towards one side of the saw, by the aid of which the cutting may be conducted in a straight line, at the required depth. The table or *base* should be fitted on rollers to move *with* the electrotype, in a direct line parallel with the saw itself, and a glass hood should be fitted over the saw to catch chips.

Roughing Lathe.—This is a lathe used as a surfacing tool; it is frequently employed in lieu of the planing-machine to "surface" up the backs of electrotypes for mounting purposes. The *chuck* is usually some arrangement fixed to a true surface-plate, by means of which the electrotypes may be clamped to the plate and revolved with it. The *tool* should in all cases be fixed in a traversing slide-rest, and must have a keen edge and acute angle to cut the backing metal off rapidly. A gauge should also be adjusted to allow of the correct thickness being left on the shell.

Planer.—This is usually a hand-planing machine, with a planed iron bed, racks, and hand-wheel, by means of which the plates may be moved under a wide knife, set at an angle to remove the metal to the regulated thickness.

Bevelling Bench and Machine.—A great many electrotypes are bevelled off by hand-filing, others by means of hand-planes on a bench fitted with gauges to set sizes. Bevelling-machines are also in use; these are used only in the larger operations. The apparatus consists essentially of a sliding-bed and a series of knives revolving at a high speed. These machines usually perform the work of the circular saw, in addition to bevelling. For plates taken on convex moulds, used in printing, another kind of planer is employed. These, and most of the machines here mentioned, are now made by Hoe and Co., of New York.

Mounting Blocks.—The wood blocks upon which the finished electrotypes are finally mounted for printing purposes are almost invariably of mahogany, well seasoned. The wood should be cut up square and flat, slightly thicker than it will ultimately be.

Besides these tools and materials, various hand appliances are employed in the "correcting" of electrotypes, for descriptions of which reference should be made to Chapter X.

CHAPTER VI.

Moulding Materials.

In most cases the reproductions of objects are not obtained by depositing electrotypes direct upon the objects themselves, but upon copies of them in various moulding materials. Thus, when it is required to obtain an electrotype of a medal's face, a cake of moulding material is prepared, and the medal is pressed upon it. When separated from the original we obtain an exact copy in *intaglio.* This copy is then deposited upon, and the final result is a reproduction in *relievo.* This is the process as applicable to flat work. When the work is rounded or undercut, as a bust, a different material and moulding method must be adopted. We are concerned with the material of which the original is made, and with its shape; and these particulars must be known before a suitable moulding substance can be selected for the purpose. The moulding medium must not in the process injure the original, and it must also withstand the effects of the depositing solution. It must, further, be either a conductor of electricity itself or its surface must readily receive the conducting substances used for the purpose; and, finally, it must not swell or alter in bulk when placed in the depositing solution. Instructions for the use of these substances are given in the succeeding chapter.

MATERIALS FOR FLAT WORK.—The standard composition which the author recommends above all others for flat metallic work and ordinary wood engravings is made as follows:—For 10 lbs. of the material cut up 9 lbs. of commercial bees'-wax, free from grit or impurities, in a warm pan; increase the heat and stir in 1 lb. of Venice turpentine, and, finally, 5 ozs. of the very finest powdered plumbago. Mix thoroughly at a gentle heat. This material will last for many hundreds of impressions if kept perfectly free from contamination with foreign substances. The after process of blackleading causes a good deal of extra plumbago to come into the composition, but it may be allowed for by adding a little more wax and turpentine, as the substance appears to require. This is for *pressed work*, which may be taken to include almost all the surfaces that come into the hands of the printers' electrotyper.

For work of the flat kind which cannot from its nature be pressed, the following material may be used:—Bees'-wax, 9 lbs.; hard mutton suet, 2 lbs.; plumbago, 3 ozs. When the mould is required to be especially sharp in the finest lines, the suet or stearine may be omitted, and 5 lbs. of resin substituted. The melting-point of these substances is about 155° F.

In addition to these materials *gutta-percha* is common, but it must always be well pressed. When carefully treated gutta-percha is one of the best of moulding materials, and it receives the conducting coating of blacklead readily. It does not alter in the solution, and preserves the finest lines. This substance is more extensively used on the Continent than in England. It should always be remembered that it shrinks while cooling, and that, therefore, much pressure is required just before it hardens into form. The kind best adapted for moulding work is simply the unmanufactured but purified sheet, about three-eighths of an inch in thickness.

Steel Plate Gutta-percha Material.—This also is flat work, but it is not usual to *press* steel engravings in case of accidents; the copies are, therefore, taken off without pressing. The material best adapted for this purpose is made as follows:—Cut up and melt *very slowly* (in a porcelain pan if possible) 9 lbs. of the best gutta-percha; stir in and thoroughly mix 4 lbs. of refined lard, and, finally, ½ lb. of good stearine. The latter is not generally employed, but it adds to the rigidity of the finer lines. To insure that the lard be free from grit and all other injurious substances, it may be melted and poured into water, which should be hot, and afterwards allowed to cool; impurities are generally precipitated to the bottom of the vessel by these means.

But gutta-percha alone may be employed as follows:—Place 9 lbs. of fine gutta-percha, cut small, in a jar which can be covered closely; pour in a large quantity of bisulphide of carbon, and allow to digest for two days. The required quantity may now be removed and heated carefully in a porcelain or iron-enamelled vessel; when sufficiently thin it may be used as directed in Chapter VII. Much care should be exercised in the use of carbon bisulphide, as it is dangerously inflammable, even at a low temperature. It gives off an abominable smell. Gutta-percha dissolved as above may be used for a variety of purposes, and is sometimes employed for "stopping off" the backs of moulding pans.

Fusible Alloy.—The chief advantage of this material is that it is of itself conductive, and requires no after preparation, except it be that the back must, as mounted by the common process, receive a coating of some "stopping off" material. It is adapted to the moulding of most surfaces not liable to injury on the application of a heat of 212° F. or a little over. It is made up as follows:—Melt 1 lb. of lead in a clean vessel, and stir in ¾ lb. of tin, and, finally, 1½ lbs. of bismuth. Stir well and thoroughly incorporate the mixture; pour out gradually into water, collect, and repeat until a complete admixture is obtained. It melts at 212° F., the temperature of boiling water. For small quantities mix lead 5 parts, tin 3, bismuth 8.

The first cost of this excellent material is high, owing to the price of bismuth, but it serves for numerous electrotypes. It *expands* on cooling, and, consequently, takes a very *sharp* impression. It also assumes a soft but firm (not thin) condition before setting, which admirably adapts it for the taking of copies by placing and pressing the warmed surface upon it just before it sets.

Plaster of Paris.—This well-known material is adopted for most purposes where the *finest* lines are *not* required, and where pressure cannot be used. It may be prepared (so as to insure its being fresh) from gypsum (sulphate of lime). The substance is heated carefully to about 500° F. If the heat should be greater than this the plaster may be worthless, and may fail to set. When all the water of crystallization is driven off the residue is plaster of Paris. When purchased it must be fresh, otherwise it will fail to set, or will set only very slowly. Before being used it should be carefully sifted, more especially if the work be small or fine, to remove accidental impurities; it should also be warmed in an oven. When used it is mixed with water to a thin paste, and poured on the article to be copied, the surface of which should first be coated with the paste by means of a brush; but full directions will be found at p. 172. Plaster of Paris should be kept in close-stoppered bottles. It is usually sold in three degrees of fineness.

Stearine.—This is a beautifully white substance, which is used both in moulding by itself and in combination with other materials. It is prepared by saponifying tallow with milk of lime. Stearate of lime is thus produced, which is decomposed by sulphuric acid; the result is sulphate of lime and pure stearic acid. Paraffin is sometimes employed in place of stearine, but it is more expensive and offers higher resistance to the currents.

ROUNDED AND UNDERCUT WORK.—Art work is usually, except in the case of flat surfaces, moulded from in plaster, wax, fusible alloy, or elastic composition. All undercut work should be copied in elastic composition if the original must be preserved.

Elastic Composition.—Copies of all kinds of work which cannot conveniently be moulded from in sections may be made in this composition. It is elastic, readily cut, can be rendered highly conductive, and springs into its proper form after being disturbed. This valuable substance is made as follows:—8 lbs. of glue of good quality is soaked until quite soft in cold water; it is then placed in a common glue-pot and mixed with 2 lbs. of treacle. The whole is heated and thoroughly incorporated by stirring. When the mould is not likely to be roughly handled ½ lb. of bees'-wax may be added to the mixture. This material is poured around the prepared object, and when set may be cut open from top to bottom and the object removed; the mould will now spring into its original position and shape.

When the elastic moulding material is placed in an ordinary depositing solution, without being previously protected, it is very apt to absorb water and swell. This may to a great extent be prevented by increasing the proportion of wax, but it is usually better to protect the surface by immersion in a weak solution of bichromate of potash and drying in the sun; an insoluble coating is thus secured. Tannic acid is also frequently employed for the same purpose; it is incorporated with the hot mixture at the rate of 2 parts for each 100 parts of glue. When care is exercised to "stop off" the exposed portions of the composition, before placing in the depositing solution, by means of gutta-percha varnish (gutta-percha dissolved in carbon disulphide), and perfectly protecting the interior by conducting substances, there is usually little danger of absorption. The rate of deposition must, however, be rapid.

The composition may be used many times. Its proper sphere is, however, not as a matrix upon which the electrotype may be deposited, but as a *preliminary* mould, as follows:—The elastic composition is poured around the object, allowed to set, slit up, and the object removed. The elastic mould is now supported by a casing of sheet metal or paper, and a *second model is formed within it.* This second model is in turn moulded from in plaster, and finally run out by heat. The plaster mould is, therefore, employed as a matrix in the depositing vessel, as further explained at p. 171.

Composition for obtaining a Cast in Plaster.—The material usually employed is made as follows:—Bees'-wax, 8 lbs.; resin, 7 lbs.; tallow, 1 lb. These ingredients are thoroughly mixed by the aid of heat and stirring. The composition should not be poured into the mould until it is nearly setting, because the heat may cause complete union between the two and render the cast useless.

When this second model is to be deposited upon direct, a little powdered blacklead may be added to the composition before pouring; and to render it fit for receiving a conductive coating afterwards the resin should be omitted and ½ lb. of the following solution substituted:—Dissolve 1 part of phosphorus (by weight) in 15 parts of carbon disulphide. Handle with the greatest possible care, as it is a dangerous substance when accidentally spilled near a fire or among rubbish. The model is then rendered conductive by other solutions and means, particulars of which are given in the succeeding chapter.

Marine Glue.—This composition is very useful in moulding and in many other kinds of work. It is made as follows:—Dissolve 1 lb. of caoutchouc in 4 gallons of wood naphtha, and allow it to stand for two weeks; further, add 2 parts of shellac to 1 of the mixture; heat very carefully, mix, and cool on marble slabs. In heating and mixing all these compounds in which bisulphide of carbon or naphtha forms a part, much care is necessary to avoid an outbreak of flames, so that the operations should be conducted out of doors over a closed source of heat, or within the building, with steam as a source of heat.

"Stopping-off" Compound.—Those portions of a matrix or an original where the deposit of copper is not required, as on the back of moulding trays in printing work, the backs of casts taken in fusible alloy, and portions of moulds accidentally rendered conductive when not required, must be stopped off to prevent the deposit from spreading upon them. Various varnishes are used for this purpose, but the least expensive and most readily applied are best adapted to the wants of the electrotyper. The most generally useful material is simply melted bees'-wax, or the ordinary bees'-wax composition, free from plumbago. Stearine may be used, also paraffin, engravers' varnish, or gutta-percha. In hot cyanide solutions copal varnish may be used, or the following:—Resin, 10 parts; bees'-wax, 6; sealing-wax, 4; rouge, 3. These are mixed by heat and stirring, and applied while liquid with a brush.

Plumbago-Blacklead.—This substance, erroneously thought by many to be a variety of lead, is in some respects identical with finely-powdered graphite, or gas carbon; it is, indeed, a variety of carbon, in combination with iron.

Owing to its adherent nature and excellent conductive power, it forms the best known and most generally applicable conducting surface for electrotype moulds. Some specimens of plumbago are found to conduct electricity freely, others are almost useless. The common varieties, used for household purposes, are almost all bad conductors, except, perhaps, Nixey's, which may be employed for most common work. The finer varieties are distinguished for their power of rapidly imparting a brilliant texture to almost any surface, with little friction, and for their tendency to cover a large surface with little expenditure of substance. It is, therefore, economy to employ only the best quality procurable, of wholesale chemists or instrument dealers.

However well ground, plumbago is apt to contain grit, or grains too large for the surfacing process; it should, therefore, be carefully sifted through muslin or a fine wire sieve, and should be stored in glass bottles protected from dust.

It is usually applied to the moulds dry, because the thinnest possible coating only is required and permissible, and because moistening the powder creates a paste, which can never be properly spread or cleared out of the finer lines of engravings in the polishing process. It is frequently sprinkled over a wax mould before impressing it, and if evenly done this plan is very useful as assisting the after process. Plumbago is always used to polish up woodcuts and type before taking impressions of them in moulding material; it prevents seizing between the surfaces. In the case of taking electrotypes of the intaglio kind direct from surfaces, plumbago polish, when it can be applied, prevents actual seizing between the new and the old metal, and assists in their after separation. It is also employed to form a part of the usual moulding compositions, and not only assists in checking the shrinking tendency, but aids the conducting qualities of the compound, and facilitates the formation of a good conducting surface. The polishing process is often injurious to health by reason of the dust raised; but this is easily obviated by the use of a glass case, a device which is frequently employed.

CHAPTER VII.

Preparation of the Work.

In this section we enter upon a consideration of that portion of the electrotyper's art which calls for all the patience and *forethought* usually found in skilful operators. The success of the depositing process depends in a great measure upon the faithfulness with which the mould is produced, and the care exercised in rendering it conductive of electricity; and these are the chief operations in electro-typing next to the depositing process itself. While the depositing process depends upon the operator's knowledge of the laws of electro-deposition, this present portion of the art relies altogether upon his manipulatory skill and his foresight.

The preparation of the work signifies the production of copies from it, in various materials, and rendering these copies fit to receive the electrotype; thus the original work is seldom employed in the actual process of depositing the electrotype; it is no longer required immediately after the impression has been secured. In some cases "preparation" may signify getting the work itself ready to be deposited upon; it will therefore be observed that in cases of the latter description, the electrotype obtained is in *intaglio*, and must be in turn deposited upon to secure a copy of the original in *relievo*.

The conducting surface is an artificial coating carefully laid upon the impression. If the substances in which the impressions have been taken are non-conductors (as most of such substances are), they must be rendered conductive over every line of their faces to receive the deposit. This conducting film must in turn be in perfect metallic contact with the negative pole of the electric source; and this connection must, moreover, be well distributed to different parts of the surface, otherwise the deposit will evince a tendency to fall most copiously upon those portions in immediate contact with the negative pole. The deposit and mould face, when separated, are found to be *perfectly dry*.

Preparation of Coins, Medals, and Small Flat Surfaces.—To prepare the surface of a medallion, for example, so that an electrotype in intaglio may be obtained from it, the back should be well varnished over with melted bees'-wax, or other stopping-off material mentioned at p. 149. This will prevent the deposit from spreading over the back. The face itself should be lightly cleaned to free it from extraneous dirt, and it should afterwards be rubbed over with turpentine in which a very little bees'-wax has been dissolved, to prevent the deposit from obtaining absolute *adhesion;* otherwise the electrotype could not be separated from the original. In most instances the conducting wire cannot be soldered to the article without marking it; in those cases the coin may be hung in the solution in a double loop of copper wire opposite to the anode. When the wire may be soldered, it should be fastened to the back of the coin, or to its edge (Fig. 21).

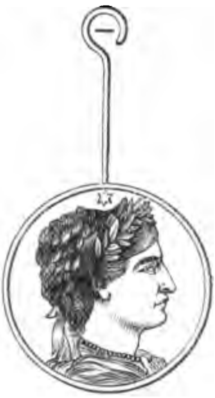


Fig. 21.—Mould from a Medal.

Medallion Depositing Trays.—The author employs for the purpose of taking electrotypes in intaglio, of coins and small circular articles, cases stamped in thin sheet copper, forming shallow circular trays, with hooks soldered to the back (Fig. 22). All parts of the trays except the circular interior are varnished over (stopped off) with japan black. To copy one side of a coin, or medal, it is thus only necessary to drop it into one of the trays adapted to its size, rub its surface over with the prepared turpentine, and hang it in the solution to be deposited upon; its contact with the back of the tray insures perfect conduction to the current. These trays can at a trifling expense be adapted, in a complete set, to take from a medallion of four inches to a coin of one-fourth inch. A set of three dozen, graduating in size by one-eighth of an inch, will be found to answer every purpose of the kind.

The same trays may be used as moulding-boxes for all flat work of the medallion description, where the electrotype is deposited upon the mould to produce a *relievo* copy. This method is most decidedly better in all possible respects than the old one of taking the mould on a cake of the composition, when a wire is employed to give contact,

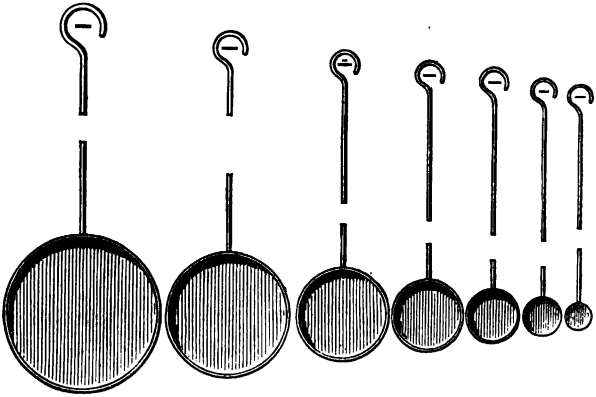


Fig. 22.—Medallion Depositing Trays.

and very imperfect contact too, aided by blacklead conduction only.

But for the benefit of those who cannot obtain a set of these trays, or incur the expense (about 5s.) of having them made, the old process of copying coins is here described.

Moulds for the deposition of relievo electrotypes of coins and medallions are made from fusible alloy, wax compound (p. 142), gutta-percha, plaster of Paris, and other materials mentioned and described in the preceding chapter.

To obtain the copy in fusible alloy, the metal is melted and poured into a holder, as a pill-box cover, or one of the trays above-mentioned. The medal is attached to a holder, and, just before the alloy begins to set, it is skimmed by passing a card over its surface, and the medal brought down and pressed tightly on the alloy until it cools. An exceedingly sharp copy is thus obtained. If the alloy is at first poured into one of the trays, it is ready for the bath as soon as its surface has been treated with the prepared turpentine (turpentine in which a little bees'-wax has been dissolved); but if it is poured into any other case, a wire must be heated and attached to its back, which must be afterwards varnished. The mould is now ready to receive the deposit.

To obtain a mould in wax composition (p. 142), a cake of the material should be poured into a depositing tray, or merely on a level surface. The medal is prepared by being cleaned over its face, and lightly dusted with plumbago, which is brushed off in circular strokes; it is then placed face downwards on the composition, and pressure applied. Any of the means suggested at p. 134. may be used in obtaining pressure. When sufficiently pressed, the medal may be detached by carefully placing the edge of a sharp knife under it at opposite sides. If the wax should have adhered to the medal the process must be repeated.

A satisfactory copy having been obtained, some plumbago is dusted over its surface, and brushed into it gently with the brushes mentioned at p. 135. In a short time a good conducting film will thus be secured. If the copy be taken on a cake of composition, a wire must be heated and fastened in the back, the blackleading being carried up to and around the wire. If the medal should be over 2 inches in diameter, the conducting wire may be made into a hoop, and should be *fastened around the edge* of the cake or mould. In this way the conducting surface can be led to the wire at several points. If the author's suggestions regarding *trays* be employed, all this trouble will be saved, because the conducting face will be surrounded by the metallic edge of the tray, and the deposition can only take place over the face of the mould. In either case the matrix is now ready to be placed in the solution to receive the deposit.

If the blackleading has been carelessly performed, the result will soon be disagreeably apparent. If there should be a defect of conduction where the wire joins the mould, all deposit upon the latter will fail, and copper will only appear upon the wire itself. If there should be defects of conduction at any parts of the mould, the deposit will fail at these parts, and holes will appear in the electrotype.

Every mould, when first put in the solution, is apt at first to *repel the liquid*, and to retain upon its surface a *film of air*, especially in the hollows.

Thus, air-holes frequently appear in electrotypes. Hence, *every mould, before being put into the depositing vessel, should be thoroughly moistened all over its surface;* this is done by allowing a stream of water to fall gently upon it for some minutes. The larger the mould the more necessary is this precaution. Large moulds of printers' electrotypes are first covered with water to a depth of 1 inch, and a stream is then directed over the surfaces by means of a hose. This is the last operation before placing in the solution.

In cases where the medallion will not stand pressure, the mould must be made in some substance which can be poured over its surface. Plaster of Paris may be employed, but the steel engraving moulding material, mentioned at p. 143, is best adapted for the purpose, and gives least subsequent trouble. The surface of the medal may either be very lightly oiled, or brushed over with a little plumbago. It should then be surrounded by a rim of gum paper or tin (a complete set of rims, in tin, should be kept), and the composition carefully poured on, beginning at the middle *in order to exclude air bubbles.* When the composition has fully set, which may take about ten hours, the rim is removed and the mould detached. This mould may be treated as a cake of composition, as directed above; but it is better to place it, back downwards, in a *medallion tray,* and to polish up its face with plumbago there; the trouble of fixing a wire is thus avoided.

Plaster casts may be copied in the same manner, but the plaster must, previous to pouring on the moulding material, be soaked in water. The same kind of work may also be copied in plaster itself. When the plaster copy is secured it should be baked to expel moisture, and must be saturated with tallow or stearine to prevent its absorbing the solution. It may, in doing this, be placed in a *shallow* layer of melted stearine, back down, and left there until the substance soaks through to the face; it may then be removed, cooled, and polished up with plumbago as usual. Again, the depositing tray may be used with advantage.

Both sides of a medallion or coin may be electrotyped by two methods. The first and most common method is as follows:—The coin is surrounded by a rim of stiff gummed paper, extending about one-third of an inch beyond its faces; the rim is thus double. The moulding material, which may be the wax mixture used for pouring purposes, or even plaster, must be poured into one side first and allowed to set, when the other side may be poured; much care should be taken to avoid air bubbles by distributing from the centre outwards. Both moulds may now be removed and deposited upon. The deposits may subsequently be mounted side by side, or may be soldered together. In some cases gutta-percha is used to take the mould with; it is softened in hot water and two balls pinched off the piece. These are applied at either side of the coin simultaneously by pressing the balls upon the centres of the faces and working out towards the edge to exclude air bubbles. Pressure must afterwards be applied, and increased as the gutta-percha hardens. The moulds when separated from the original may be fitted into medallion-trays, blackleaded, and deposited upon, or, in the case of no trays being at hand, wires must be heated and fixed in the backs and the blackleading continued around the wires.

Another plan may be adopted, as above suggested, and it is the better of the two. A disc of stiff shellac-varnished paper is cut one-third larger in diameter than the medallion, and a circle the exact size of the latter cut from it by means of a punch or a sharp knife. The flat ring of stiff paper thus obtained is to be fitted over the edge of the medallion to the central line; it thus, as it were, divides the medallion into two equal discs or halves. The medallion is then carefully rubbed over with prepared turpentine, and placed in a wire stirrup to be deposited upon. It may be hung near to an anode and turned on the stirrup every few hours until two thick deposits are secured; these deposits will be found separated by the paper ring. When removed from the depositing vessel the electrotypes may be separated from the original by running a thin knife around between them, and rapidly heating both coatings; a few taps usually separates them. Thus two *intaglio* copies are secured at once. If it be desired to obtain one complete copy in any of the softer metals, fusible alloy may be employed as follows:—Place one side of the trimmed electrotype face up in a stiff cardboard ring; melt some fusible alloy, and skim it; pour the alloy to a moderate thickness on the electrotype face, skim it, and instantly place the other half above the alloy, face downwards. A little pressure will force out the superfluous metal and secure an excellent and sharp copy of the original in fusible alloy.

Or, commencing again at the beginning, two copies, one of each side of a medallion, may be secured as follows:—Pour a cake of wax composition into two medallion-trays; rub the medallion over the faces with plumbago, press one face and take a copy in one tray, and, when removed, in the other. These moulds when polished with plumbago are now ready to be deposited upon. The trimmed deposits may, if desired, be soldered together or exhibited separately.

The various methods applicable to the moulding and preparation of coins and medallions have thus been described. The new method of employing medallion-trays greatly simplifies the whole operation, and allows of its being accomplished in one-fourth the ordinary time with greater certainty of successful deposition.

FLAT PRINTING SURFACES.—We now enter upon a more important division of the subject, where the composition, pressure, and blackleading all call for careful selection and accomplishment.

Flat work includes engraved wood blocks and type set up in the usual formes. Matter to be electrotyped should be set up with high spaces, otherwise plaster of Paris must be employed to raise the lower levels. Low spaces, when the matter is moulded, cause long projections of the moulding composition to protrude from the general surface of the intaglio copy. These spaces not only prevent the operation of blackleading being performed satisfactorily, but act in the worst manner in collecting the deposit upon themselves when in the solution, to the proportionate weakening of the letters, which lie *much deeper* in the moulds. When a mould must be taken from low-spaced matter it will save much subsequent trouble to proceed as follows:—After the matter has been reimposed and arranged level, pour plaster, in a thin paste, on the face and rub in by hand; just before the plaster sets apply a rather stiff brush to remove all plaster from the general surface of the forme and the beards of the letters. The object is to reduce the hollows by filling up as much as possible consistent with clearness in the printing. Set the type up to dry the plaster, and afterwards go again over the face with a stiff brush to remove all trace of plaster from the letters themselves. This process is technically known as "floating."

To prepare the set-up type for moulding, after proper planing and locking-up, the letters are brushed over with the lye to clear off all traces of old ink. Upon the dry surface is sprinkled a quantity of finely-powdered plumbago, which is then polished all over the surface with a moderately stiff brush. When wood blocks are present a softer brush should be used. After a good polish is secured, all loose dust must be removed by the brush and blowing with the breath. The matter is then ready, after a final examination, for the moulding process.

Wood blocks are prepared much in the same way; they are carefully cleaned off with turpentine, examined, and allowed to dry. Blacklead is then sparingly applied and well polished with a soft brush; loose dust is blown away, and the surface is ready for moulding.

The blackleading process is doubly useful; it prevents "seizing" between the surface and the moulding composition, and it leaves a slight coating on the mould, which both assists the subsequent blackleading process and insures conduction to every hollow.

The moulding composition mentioned as "standard," p. 142, is now prepared, and when ready is poured evenly into the level depositing-tray (p. 133). The tray is *filled* and the setting surface watched; air bubbles must be quickly and decisively broken and the surface arranged to set level. If it begin to fall in the centre, quickly fill in more hot composition, and run a rule or side-stick over the surface. The composition sets very quickly, especially in cold weather, unless the tray be warmed before pouring in the composition.

A final examination of the mould composition and type or engraving is made before moulding. The type or block is placed upon the clean and level bed of the press, face upwards, and the mould-tray lifted over it, face to face. Care should be taken to so arrange the mould-frame that the impression may fall centrally, otherwise much damage may be done to the type or block. The press is now set into action, and a gentle squeeze given. The type or block is then lifted carefully off the mould-face to find whether they have "seized;" if not, they are again placed together, care being taken to insure that the surface shall "fall fair." The sense of touch usually guides the operator at this stage, but a gauge may be used. A good deal of pressure is now applied, and the mould and type or block finally released.

In some establishments it is usual to carefully finish the surface to guard against "seizing," and to neglect the preliminary examination mentioned above. In either case care is necessary in separating the surface and mould after the final pressure has been given. It is usual to employ a pair of chisel-like levers for this purpose, one being placed under the mould-frame at either end, and the mould forced gently upwards. The sides are next released, and the mould lifted cleanly off the surface. A close examination will reveal whether the copy is perfect and unbroken. If the pressure has been too great the mould is apt to seize, and if too light, it is not impressed to a sufficient depth to insure clean printing.

Small surfaces can be moulded by light pressure, but large surfaces require a pressure of several tons. Hence it is impracticable to give figures as to the exact pressure required. A skilful workman can soon discover by the sense of touch whether he is pressing too much or too little. The appearance of the forced-out margin of wax is also a guide.

Electrotypes before being moulded from should in all cases be removed from their blocks; this may be done by means of a thin chisel-edge; bending must be particularly avoided.

The mould, when secured, is trimmed and "built" by a special workman before being blackleaded. The chief object of this operation is to raise the general level of the hollows to insure the required depth of the electrotype in the "whites," where it is apt to black in the printing process. The hollows are built up by the aid of a knife and melted wax, and a smooth surface produced. A hot building-tool is also employed, from the taper point of which wax is run into the required portions of the mould. Matter that has been moulded from (with low spaces) without being "floated" gives much trouble at this stage, because these numerous projecting pieces of wax must be removed with the knife, and much care and skill are necessary to avoid injury to the mould.

The conducting surface to be given to impressions is the next consideration. In the kind of work above described blacklead is almost universally employed. The finest quality only should be used. (See p. 149.) It is dusted evenly all over the surface, and if the work is to be done by hand, one of the blackleading brushes spoken of at p. 135 must be employed. The powder is first beaten into every portion of the surface, and then gently rubbed in circular strokes until it adheres to the impression without danger of leaving naked spots when placed in the depositing solution. The blackleading must be continued to include the edge of the depositing tray at all points. The main object is to obtain an equal distribution of conducting power all round the blackleaded surface. The negative pole contact from the battery is, of course, secured by fastening a pair of hooks in the upper part of the tray as usual.

Blackleading by machinery has already been described (p. 136); the process should not be carried further than to obtain a good surface all over the mould.

Before placing the mould in the solution to receive the deposit it must, if the tray should be of the old type (p. 133), be "stopped off;" that is, the back and sides must be protected by a layer of varnish or moulding composition to prevent the deposit from spreading over these portions. If the mould should be made in one of the insulated trays (p. 133) the stopping off will be unnecessary.

The last operation to be performed, previous to depositing, is to moisten the whole surface of the mould, as explained in connection with medallions.

Place the mould face upwards and cover with water to the depth of an inch; then direct a gentle stream against it from a pipe and rose. In a few minutes the surface will be thoroughly moistened and freed from air; an examination should, however, be made just prior to placing it in the solution, and the camel-hair brush passed over any suspicious-looking portion.

The depositing process and final preparation of the electrotype for printing are treated in distinct chapters; therefore we pass on to a consideration of the method of preparing a mould from—

Steel Engravings.—This work is different in many respects from ordinary flat surface operations; it is much more delicate, and should be performed with special care at every stage of the process. Pressure is seldom used, and in fact is both unnecessary and injurious, because steel engravings are shallow in the "whites" and apt to be twisted.

The operation is commenced by thoroughly cleaning the steel-plate and freeing it of the wax usually spread upon it for protection. This is most effectually done by boiling for a quarter of an hour in a strong solution of caustic potash (avoid injury to the hands by this compound). Remove and wash thoroughly under the tap; dry by rubbing with a soft linen cloth, and finally wipe with a pad of cotton moistened with spirits of wine.

Surround the plate, which must be laid face upwards on a level surface, with iron bars to form a boundary for the composition, and have in readiness the moulding material described at p. 143. Pour on the composition, beginning at the centre or at one corner, until it spreads all over the face to a considerable thickness. Leave to set, and in ten hours remove the mould; it should come away without difficulty. Examine the face of the mould minutely, and proceed to form a frame of angle pieces of thin sheet copper, soldered together at the corners. These strips should grasp the mould firmly all round its edge, and must serve the purpose of a depositing tray by having two hooks soldered to one of the sides. But the mould may be laid face up in a square depositing tray of the medallion description instead.

To render the face of the mould conductive proceed as follows:—The conducting facing suited to this class of work consists of a film of precipitated silver. Dissolve a piece of phosphorus in 2 drachms of bisulphide of carbon, stir in 2 drachms of benzine and a drop or two of sulphuric ether; pour the whole into half-a-pint of spirits of wine, and wash the surface of the mould with this mixture twice, allowing it to dry after each application.

The silver solution is made by dissolving 1 drachm 20 grains of nitrate of silver in a mixture of half-a-pint of alcohol and 1 drachm acetic acid. The mould is thoroughly floated once with this solution and allowed to dry spontaneously.

Another and simpler method of rendering the mould conductive is in use, and may be described as follows:—Dissolve phosphorus in pure alcohol until a strong solution is obtained, and wash the mould with the mixture. The silver solution is prepared by dissolving nitrate of silver in aqueous ammonia to saturation. It is to be poured evenly over the surface of the mould, and allowed to float over it for a few minutes; the solution is poured off, and the mould allowed to become partly dry, when it is again floated with the mixture. Spots that do not appear to take the solution readily should be wetted with it by means of a soft brush.

All printing surfaces may be moulded from and arranged for the depositing process by either of the foregoing means. Gutta-percha is sometimes used as a moulding material, but it usually requires the exercise of too great a pressure to be generally applicable, at least to set-up type. In the case of moulding engravings upon a sheet of gutta-percha, the material should be rolled into a large ball by softening in hot water, applied to the middle of the surface to be copied and gradually worked out to the edge to insure the expulsion of all air. Pressure is then applied, light at first, but increasing as the material begins to cool, and heaviest when it has begun to set; in this way the well-known shrinking qualities of gutta-percha may be compensated for. In cases of lines extending across the page, in depositing from set-up type, the electrotype is very apt to be weak at those points, but they may be strengthened by stopping off the general surface at the back, wetting the weak lines with a solution of nitrate of mercury and depositing again upon them.

ART WORK.—This class includes all kinds of work not confined to the printers' electrotyper; natural objects, reproductions of art works in plaster or other material, and especially such objects as present unusual difficulties in moulding. A knowledge of the art of casting or moulding, however slight, will greatly aid the operator at this stage. Printers' electrotypers usually confine their operations to the reproduction of printing surfaces; the art electrotyper, on the other hand, is prepared to reproduce both flat and rounded objects, plain or undercut. He deposits his reproductions on both interior and exterior surfaces, works with every possible shape of anode, and every useful combination of negative leading wires.

The first consideration is the mould. Any·one of three processes may be selected for the purpose, according to the object or the material. 1st, the object may be moulded from in elastic composition, instructions for making which are given at p. 146; 2nd, the object may be moulded from in two or more parts at a time, by the usual methods of casting; and 3rd, the object may be moulded from all at once, and afterwards broken out of the matrix. This latter method is known as waste casting.

To copy a rounded object, such as a bust, in elastic composition, it must first be made heavy, to allow of its sinking in the composition when poured; this is usually done by filling it with sand, and pasting a paper cover over the aperture. The bust is then placed in position in a *tapering* vessel, such as a common water-pail, and the position of the back marked upon the vessel in chalk. The composition being ready, it is poured steadily into the vessel until it fully covers the bust, and it is allowed to set for twenty hours or more. The whole is then carefully shaken out of the taper vessel, and a slit made through the composition with a sharp knife, down the back, from the top of the head. By careful handling the composition mould may now be opened, and an assistant may *withdraw the bust from its interior.* The elastic mould, when released, should close up to exactly the original shape. The interior of this mould may be deposited upon, but the process is troublesome, and not to be recommended. It is always best to form another bust, of the composition described at p. 147, within the elastic one. This is done by supporting the elastic mould, and pouring the composition into it at the open end. The composition should be as cool as possible consistent with free pouring, so that it may not injure the elastic mould and deface the resulting duplicate.

The duplicate thus secured is in turn supported in the taper vessel, and a mould made by pouring in plaster of Paris composition as a thin paste. When this is set the whole is removed, and the duplicate *melted out* by heat. If the pair are placed together in a suitable vessel in an oven, an hour or two will cause the interior figure to melt out and fall clear of the plaster mould. The latter may be rendered conductive within as follows:—Wash out twice, allowing the surface to dry each time, with a solution of phosphorus 1 part, bisulphide of carbon 15 parts. Afterwards wash out carefully with a solution of nitrate of silver, one dwt. to the pint of water. The conduction is further improved by washing out also with chloride of gold solution. The negative conducting wire must be attached to a rim surrounding the open aperture of the bust, and two or three wires should lead from this to the most remote parts of the mould, otherwise the electrotype will be weak at these parts. The anode should also be hung down in the mould beyond the mouth of the aperture, according to the depth of the mould. It is always advantageous to make an aperture in the head of the mould, at the back, to allow the solution to pass out there if set in circulation at the top. It is assumed, in this case, that the mould is placed in the solution in a vertical position, and the anode suspended within it.

But the quickest and surest way by which these objects can be copied is to secure, from the composition duplicate, or from the object itself if it can be oiled, a pair of halves as follows:—Bed the object to half its depth in fine sand, level the surrounding surface, and fasten a pair of guiding pegs in the sand. Surround with an edging, and pour on thin plaster-paste to the required depth; or, if required very accurate, rapidly brush over all the crevices with the paste before pouring. When set, remove from the sand and reverse, treating the opposite side in exactly the same way; a little oil may be spread over the surface where the two halves meet. When separated from the original, the halves can be dried and rendered impervious by allowing them to stand in a shallow dish of melted stearine. And, finally, they can be properly blackleaded in the ordinary way to render them conductive within. The negative pole connection should be arranged in the shape of a rim of thin copper sheet, or a wire previously bedded in the plaster; in all cases the blacklead facing must be carried over the rim thus placed.

The electrotype obtained by these means will be in two halves, which, when trimmed, should be soldered together, and the joining-line bronzed over.

All kinds of round objects, not much undercut, can be moulded and electrotyped by the above method. In the case of deep undercut surfaces, elastic composition must be used.

In the moulding of large objects, it is usual to adopt the third method previously referred to, and to destroy the original, which at the commencement is treated as follows:—When the model is of plaster, its surface is first saturated with linseed oil, allowed to dry, and coated carefully with a highly polished film of blacklead, as usual. It is then arranged in the depositing vessel, and coated all over its surface with a good substantial shell of copper. When removed from the vat, the shell is cut through at convenient lines, or in two complete halves, and the interior plaster-figure is sawn through. When separated, the sections are freed from the plaster by removing it piece by piece. When completely freed from all traces of the model, the sections of copper are "stopped off" (after affixing guidance wires) with varnish, the interior treated with prepared turpentine, re-immersed in the solution, and deposited upon to the required thickness. The outer copper shell is now removed, and the deposit proper is complete and ready to be soldered together to form the full figure. This process is expensive, but it is accurate and sure. Many of the largest statues turned out by Messrs. Elkington are made by this process.

In most cases it proves cheapest to obtain models and section moulds of an object from a regular caster. Wax composition of the various kinds described in the preceding chapter may frequently be used in obtaining sectional moulds.

Moulding is not electrotyper's work; it should always be left to hands practised in that distinct art. The electrotyper proper is only responsible for the depositing process, or at most for the conduction surfacing, and the production of the required shell. In most cases, therefore, the moulding process, when difficult or complex, should be left to a special workman. Hence, the art of moulding should never be carelessly mixed up with that of electro-typing, or considered except in the light of a preparatory operation.

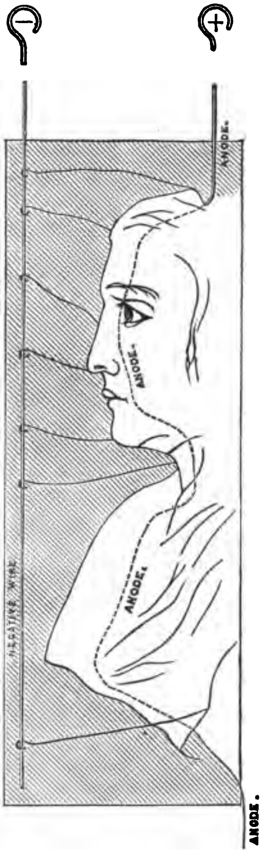


Fig. 23.—Example of a Bust Mould, exhibiting Leading Wires.

Leading-wire Systems.—In all cases where the surface is of any considerable extent, and especially if it be much undercut, great care should be devoted to the arrangement of a good leading system, otherwise the deposit is apt to be strong at one part and weak at another. Wires should be led from the main hook to those parts of the mould farthest from the anode (Fig. 23). In some cases the ends of those wires may be fixed in the mould; in others they must only touch it. The deposit is always strongest upon those points nearest to the anode, and in best connection with the cathode hooks; therefore a combination of both should be employed to lead the deposit first to the more remote corners and recesses of the mould (Fig. 24). Air bubbles must be expelled, if they form, by disturbing the solution, or gently rubbing over the surface with a camel-hair brush. Frames of conducting material should be arranged to surround the mould, and effect an equal distribution of the negative pole.

Hints.—Care must be taken not to stop all chance of deposit, by allowing the anode by accident to touch any part of the mould or negative system. The same care must be devoted to avoid bad contacts and points weak in conducting power. Almost all surfaces can be rendered conductive, without blackleading, by means of the phosphorus

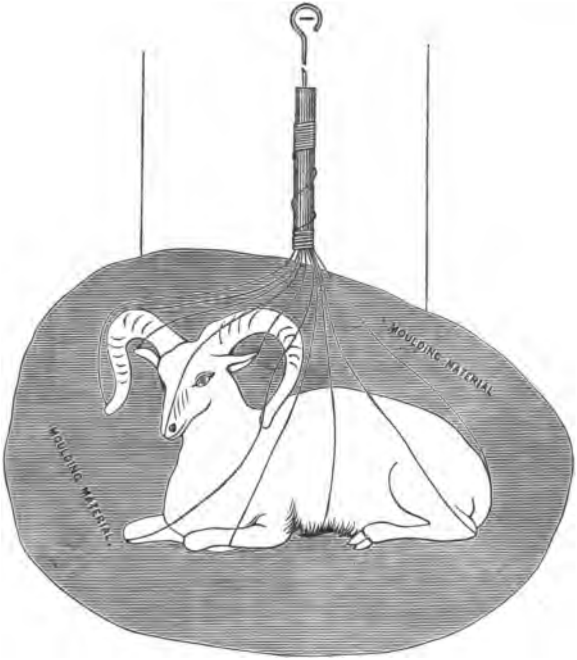


Fig. 24.—Example of an Art Mould, showing Leading Wires.

and silver nitrate solution previously mentioned. The blacklead employed (p. 149) should be of the finest quality only, and care must generally be taken to secure a high polish. Some surfaces can be blackleaded dry, others should be breathed upon or held over the vapour of spirits of wine. In the case of silver conductive films, the depositing should always at first be rapid.

Bronze powders of different kinds have frequently been recommended as suitable to the production of conducting surfaces. The finest gold bronze may thus be employed, mixed with the plumbago. Mr. Gore recommends white bronze powder of the best quality. All these metallic powders may be used with the most satisfactory results in art electro-typing, where the finer lines are of little consequence; but they must not be employed in electro-typing fine engravings, although often of use in copying set-up type. The plumbago itself may be gilt, which greatly improves its conducting power:—Dissolve 1 part gold chloride in 100 parts of sulphuric ether in an open vessel; add 50 parts of finest plumbago, mix perfectly, and expose the compound to the sunlight, frequently stirring it until dry. It is applied in the usual way. In taking moulds of rough and large objects by pressure, a thin coating of fine white bronze powder may be dusted over the substance to form the mould; the blackleading may afterwards be carried out with much greater ease.

Printing surfaces, especially of type, should not be electrotyped upon moulds rendered conductive by the phosphorus and silver method, because the deposit is always brittle at the surface, and set-up type shells are generally very thin, especially at the heads of letters and lines.

Failures.—These make their appearance in and after the depositing process; but they are usually due to some part of the preparatory work being neglected. Failures are very rare when the mould has been properly made, and its surface carefully blackleaded, or otherwise rendered conductive. Holes through the shells are due either to non-conducting spots or to unequal distribution of the negative pole; small pin-holes are usually caused by gas, due to too strong a current, or to air bubbles, which may be swept off. A total failure of deposit can always be traced to a failure of the current, either through the battery or at the contact points. Partial failure of deposit is usually due to careless facing with the conductive substance, or to a very partial distribution of the cathode pole. These defects should be arranged for and foreseen in the preparatory process. Dirty deposits are usually due to dirt from the anodes. Electrotyped copper is generally clean, and should be used when this troublesome fault appears; the defects may also be due to faults in the surfacing. The succeeding chapter is devoted to a description of the depositing process, which should be partly understood before even facing a mould is attempted.

CHAPTER VIII.

The Depositing Process.

IN the preceding chapter and the present one the two most important operations in the electrotyper's art are dealt with. The depositing process, which is now to be described, is the most interesting in the whole art, because by its aid we obtain the actual electrotype, and reap the reward of all the patience and skill we may have devoted to the acquisition of fundamental knowledge and the mastery of manipulatory details.

The preparation of representative types of the various kinds of work likely to pass into the hands of electrotypers has been fully described; which means that we have obtained moulds upon which electrotypes are to be deposited, prepared objects themselves for direct negative electro-typing, and carefully provided each with a good conducting surface, and also with the necessary leading wires or single connections; the work is, in short, ready to be hung in the solution to form the electro-type.

In Chapter V. is described all the apparatus employed in the depositing process, and we must refer back to that section if not fully acquainted with the construction of the depositing vessel and its furniture. The battery, or source of power, is spoken of at length in Chapter III., and to the concluding portion of that section reference should be made in case of doubt as to the way in which the action or connections are regulated to obtain more or less current or electro-motive force. In the present chapter will be given many details regarding the employment of electricity in depositing, but they will be found to prove insufficient unless studied in conjunction with the portion of Chapter III. just referred to.

The Various Processes of Deposition.—Reference to Chapter I. will afford information as to the various methods adopted in depositing copper electrotypes, but, from a fundamental standpoint, they are all the same, with modifications in the arrangement of vessels and source of electricity. It will further be observed that throughout this work only one method or process is recommended for operations of practical importance. This process consists in the employment of an independent source of electricity and a simple open depositing vessel of a size suited to the magnitude of the operation, with leading wires and anode.

Single-Cell Method.—This process for producing small electrotypes has been partly described at p. 25, but a number of important points in the after-process remain to be dealt with in this place.

The method from first to last is only well adapted to experimental work or to instruction combined with amusement; but it is extensively practised on the Continent in the production of even large electrotypes. It is, however, too slow, and is not applicable in cases where the electricity required is derived from other sources than zinc and sulphuric acid.

Assuming the matrix or cathode to be ready for immersion in the solution, it should be carefully noted whether the zinc-wire (negative pole) is clean where the work touches it, and that its connection with the zinc itself is without doubt metallic and clean; any fault at those points, or at the conjunction of the conducting face and leading wire of the matrix, will either greatly retard the progress of the work or entirely stop the current.

It will be observed that this process may at any time be conducted in a common Daniell's cell by simply removing its copper cylinder. The single-cell process is merely the working through itself of a Daniell-cell current, because the matrix to be deposited upon serves the purpose of the copper cylinder or negative element.

When the mould is hung in the solution, a deposit of copper is at once observed to form upon the wire. This preliminary deposition enables the operator to determine whether his current is of the required strength to produce malleable copper. If the deposit should appear very pale, and be slow in forming, it may be assumed that the current is too weak. This is remedied by either placing the mould nearer to the porous cell, or placing an additional drop or two of sulphuric acid in the latter. If the deposit should appear of a very dark red or black, it indicates that the current is too strong; this may be remedied by placing the mould farther away from the cell, or by lifting the zinc partly out of its exciting liquid. It is better to see the copper appear rather dark than the reverse. When a good colour is obtained, the deposition may be allowed to proceed; the temperature should not be under 60° F. The effects of temperature are very marked in the depositing process, a difference of a few degrees often giving rise to failure. If the temperature be higher than 60° F. the current will prove more vigorous, and the reverse with a lower temperature. The deposit will spread slowly, commencing upon the wire, over the upper portion of the mould, usually around the edges, and finally all over the face. When it becomes as thick as brown paper, or good writing paper, it may be removed from its matrix by *gently* heating it. The whole should be plunged in warm water in doing this; but in any case the deposit should not be overheated or dragged off the mould forcibly.

When the electrotype of a medal is intended to exhibit one face only, it should be strengthened by a backing of lead and tin, but pitch or shellac may be employed for small work. (See *Final Preparation*, Chapter X.)

Holes in the electrotype are generally caused by defective facing with blacklead, or by removing the deposit before it has attained a sufficient thickness. It will be observed that the deposit is thickest upon the prominent points of the matrix and thinnest in the sunk parts, so that in removing it should first be insured that a sufficiently strong shell has been deposited throughout. In depositing, the face of the mould should always be turned to the porous cell, or one face at a time if both be conductive. If the mould or object should be round, it must be slowly turned towards the cell as the deposition proceeds, *because the thickest deposit is always made upon the nearest points of the cathode.* Hence, if we take a copper plate and bind it to a V shape, slinging it in the solution so that the apex of the V may be nearest to the cell, we shall obtain a deposit beautifully *graduating in thickness* as the sides recede from the zinc. The deposit is thus thick at the apex and thins off upon the sides.

The time occupied in depositing a copy of a medal or a small engraved block depends greatly upon the size of the cell and work. In a cell capable of containing two quarts, about 10 grains of copper per hour may be expected, because the current may prove less than a veber, which will give a deposit at the rate of 17 or 18 grains. Twenty-four hours may be taken as a general average; but when the electrotype is required to be quite rigid, with no after backing, it may be made of any thickness, say, up to $\frac{1}{16}$th of an inch, which may require the action to be continued for a week. In any case it will be found that for small cells about 10 grains will be deposited per hour, and 20 grains in large cells. In the case of continuing the action for some time, the instructions given at p. 50 for the management of Daniell batteries fully apply to it.

Nodules are small projections upon the electrotype when a thick shell is required; they are troublesome, because they divert the force in their own direction and increase in size very rapidly. It is usually best to remove the electrotype and file them off, cleaning the surface again by a dip in nitric acid; after which the deposition may proceed. Sometimes these troublesome projections may be nipped off with a cutting pliers.

When the electrotype is first detached from its mould it presents an extremely rich and beautiful appearance, which is speedily destroyed by exposure to the air. Should it be desired to retain it as much as possible, the surface may be *warmed* (heating above a certain point will destroy the colour), and pale lacquer applied with a camel-hair brush. Only a very thin coating should be brushed on. Or it is common to colour the surface by *bronzing* and other methods.

Brown Finish.—This is easily obtained by moistening the face of the electrotype with water to which a little nitric acid has been added, allowing it to dry, and then gradually heating it until the required shade is obtained. Many beautiful effects may be obtained by producing a dark brown, and then brightening some of the prominences by rubbing with a cloth or leather dipped in aqueous ammonia. The dark coating is oxide of copper. A more permanent effect may be produced by rubbing the electrotype face all over with rouge and finally covering with rouge and heating to near redness.

Black Finish may be obtained by dipping repeatedly in a weak solution of platinum chloride, or by polishing up with plumbago, or by holding over the smoke of burning straw. Other methods, especially applicable to busts and the larger electrotypes, will be found described in Chap. X.

THE STANDARD PROCESS.—It is assumed that the reader is already acquainted with the source of electricity to be used, as described in Chapter III.; with the solution from which the electrotype is to be deposited, as spoken of in Chapter IV.; with the depositing vessel described in Chapter V.; and with the preparatory methods recommended in Chapter VII.

Flat Work.—The method by which flat electrotypes may be deposited is not in some particulars adapted to hollow or round work. Flat work is the most easily managed. It includes all kinds of wood engravings, flat works of art, and formes of set-up type, with and without woodcuts.

The most essential particulars relating to leading and connecting wires are given in Chapter VII.;

and in the case of woodcuts and formes of type, where moulding boxes are employed, no difficulty will ever be met with, because the connection with the blackleaded face is good throughout. But when metallic moulding boxes are not employed, and the mould is taken on a body of gutta-percha or other substance, the case is different, as the conduction, if simply arranged to begin at one point, will cause the deposit to be heaviest at that point, and will retard the spreading of the deposit. It should be observed that all the leading connections are well distributed about the matrix, and that the battery connections are cleanly made with both anode and cathode rods. It is very important also to observe the preliminary moistening mentioned at p. 167.

To commence operations, the mould being ready and the solution in its vessel, the battery should be set in action. One cell of a Smee, bichromate, or Daniell battery, if large, will suffice for the *main* deposit; but to drive the copper over the blackleaded face at first requires in some cases two cells, or a higher electro-motive force. In any case, two cells joined together for electro-motive force will hasten the first coating; even three cells may be used if the work be over a foot square. In like manner the thermo-electric or dynamo-electric currents should be regulated to give much force at first.

Lead a conductor from the positive pole of the electric source to the anode rod of the depositing vessel, and another from the negative pole to the cathode rod (it will be remembered that the cathode in our case is the surface receiving the electrotype). Select a plate of clean copper for the anode, with a surface equal to the cathode, and hang it in the solution from the anode rod. Hang, also, the cathode from its rod. The distance between the two cannot be stated without also knowing the strength of current and other particulars. They may at first be placed six inches apart, if large. The copper will first appear at the edges of the conducting frame, or upon the wire. Its *colour* and *appearance* will show whether the cathode is too near to the anode. If the deposit should exhibit a rather dark colour it may be left alone, as greater surface will remedy that and give it a lighter appearance; but if it be in the shape of black grains the plates must be separated. When the deposit begins to form upon the mould itself, its progress will be but slow until it has quite covered the surface.

Hard Brass-faced Electrotypes.—When copper is deposited slowly upon a mould from a printing surface, it tends to be harder than when deposited quickly. But it does not usually answer the purpose to deposit slowly: too much time is consumed, and the metal is apt to be too brittle.

The author, in the course of some experiments, fell upon a method by means of which the electrotype can be faced from the commencement with a very hard alloy of copper and zinc. This facing presents all the advantages of a copper face, lasts twice as long, costs little extra, and, moreover, takes the coloured inks readily without apparent deterioration.

The solution employed is simply a copper one, in a separate vessel, which has been worked with a rolled brass anode until an alloy deposit could be secured upon a blackleaded mould. The quickest way is to make up a brassing solution, as directed at p. 115, and to work this with a pale brass anode. What is required is a preliminary deposit of hard alloy upon the mould. The battery power should in all cases be greater than that used for copper alone. With moderate battery power the facing deposit will require more time than usual.

The prepared mould is placed in the facing solution and a thin deposit thrown all over its face. It is then transferred quickly to the ordinary copper solution, and finished as usual. More than ordinary care should be taken to prevent gas from settling in the hollows of the mould in the facing solution. The battery power should be equal to two or three Bunsen cells. A pale deposit secured slowly with moderate battery power is harder than the same deposit precipitated quickly with great battery power; therefore the facing deposit should be arranged to form slowly. If too pale the deposit will be soft, and if too red it will be soft. A medium can be struck between the two, when the maximum of hardness and the minimum proportion of zinc may be precipitated. In Chapter IX. this method is mentioned in connection with brass-facing, and some further remarks made upon its working. It is applicable to copies from steel plates and wood blocks, and may be used with advantage upon moulds taken from type. Brass, of whatever quality, is always much more difficult to deposit than copper; and to those unacquainted with its nature some preliminary difficulties are presented in the working of this process.

Precautions against Gas Bubbles.—A wide camel-hair brush should be passed over the face of the mould two or three times while the deposit is *forming*, care being taken to reach the hollows, because gas is liable to accumulate in them and cause holes to appear in the electrotype.

Temperature is of great importance in electro-deposition; a fall of a few degrees will necessitate the employment of greater battery power; 60° F. is the best working temperature.

As soon as the copper has completely covered the surface of the mould, one of the cells, if two be used, may be disconnected and the work allowed to proceed with one cell, or both coupled for quantity. In most cases the plates may be approached more closely together as soon as a complete deposit is secured. It should be a rule to work as near to the anode as possible, so far as good copper may be obtained; in fact there is little danger of bad metal being deposited after the mould is quite covered. The current may be augmented according to the speed required. A slight addition of caustic soda to the solution will quicken the rate of deposition.

With the fullest current which may be applied, a good shell from a flat surface may be deposited in five hours. This is very rapid work. From eight to eighteen or twenty hours is the general time, according to the current employed and the skill of the depositor. A skilful electrotyper can work with dynamo-electric current at a very rapid rate. In America electrotypes of set-up type and blocks are frequently deposited in less than five hours; indeed, they are often finished and in the printing-press within five hours of placing the mould in the depositing vessel.

As a general rule the electro-motive force of one cell is made to both start and keep up the deposition, but time is saved by employing two or even three cells at first. This applies so far as the forcing of the deposit all over the mould is concerned. When it forms a complete covering, however thin, the tension should be reduced, because it is expensive and not necessary. Afterwards, until the electrotype is complete, the cells may be joined up for quantity. A 10-gallon Daniell or Smee cell should deposit at the rate of (at least) about 51 grains per hour. This is the work of three vebers in a low resistance. Two cells should do double this work when coupled for quantity.

During the deposition frequent motion of the cathode is advisable, especially when dealing with thick deposits, because vertical lines, usually presenting an appearance of a large note of exclamation (!), are found upon the back of the plate. When the mould is frequently shifted, or kept in motion in the solution, the metal is more regularly deposited.

In the case of working with the dynamo-electric machine it is especially necessary, owing to the rapidity of the process, to *keep the solution in motion.* In some cases this is done by means of a screw, similar to a steamboat propeller, which is mounted upon a short shaft supported upon two plummer-blocks in the vat, at one end. The motion is given by a band which is driven from the shaft that rotates the dynamo-electric machine. In this way, as the propeller and band are at one extremity of the vat only, the operator is free to occupy with his work nearly the full length of the vat. The propeller-shaft may be hung horizontally or vertically. In any case the propeller should be about 8 inches above the bottom of the vat. The continued motion gives a regular rotation to the solution. In some cases the mould itself may be moved, but it is usually better to rotate the solution. Wire nets are frequently employed to separate the bottom sediment and prevent it from rising to the surface of the liquid and mould.

Faults and Failures are always caused by defects in the solution or mould, or in the battery. One of the most troublesome of faults is due to want of care to free the mould from hydrogen gas *when employing a strong current.* These gas bubbles cause pin-holes. The pin-holes may also be caused by faulty blackleading. These holes cannot be discovered until the electrotype is removed from its matrix and held up to the light. When working with a strong current it is advantageous to dissolve a little chlorate of potash in hot water and stir it into the solution. This is believed (as it contains so much oxygen) to act as an absorber of the hydrogen; but in any case the camel-hair brush should be passed lightly over the mould two or three times during the process of covering the mould.

No mould while receiving a deposit should be removed from the trough for any considerable time or until it becomes dry. In the case of its being necessary to remove the mould, it should be kept under water until it can be replaced in the solution. Nor should the fingers be allowed to touch the mould or deposit, except under water; the slightest trace of foreign matter will prevent adherence at that point.

Thickness of Deposit.—The usual thickness of shell is about $\frac{1}{32}$nd of an inch. It may be ascertained by removing from the solution and with a knife gently raising a corner (the thinnest corner) of the deposit. When satisfied that the shell is sufficiently rigid and complete it may be removed from the solution.

Separation of the Shell from the Matrix.—When it is decided that the deposit has attained a sufficient thickness (minimum $\frac{1}{32}$nd of an inch) wash well in cold water, and afterwards pour hot water on the back of the shell. This will have the effect of melting the wax composition and releasing the shell, which should now be carefully rinsed in both hot and cold water and held up to examine for pinholes. When only a very few small holes are found they may be marked, and the plate laid aside to be completed, backed, and mounted. The deposit should be rejected if holes appear upon the lines of the engraving, or upon type, so as to render it difficult to repair them. Further information regarding the process, but generally applicable, is given further on.

Electrotypes from Steel Engravings. — This is known as "fine work," and the matrix is prepared as directed at p. 168, finishing with the conducting solution. The deposit of copper is secured in exactly the same way as in the foregoing instances, but the electrotype required is much thicker, and frequently takes from one to two weeks to deposit. The thickness varies with the size, but a general gauge is $\frac{1}{16}$ inch, or more than double the ordinary thickness. A light metallic frame should be used, by means of which the mould may be hung in the solution without risk of warping. The first deposit should be driven on quickly by the aid of high electro-motive force. The greatest care should be taken to turn out such electrotypes as perfectly as possible, because they are expected to exhibit all the excellent features of the original. All such electrotypes of steel-plates are afterwards "*steel-faced*," a process which is described in Chapter IX.

Finishing Details.—These will be found applicable to all classes of work in Chapter X.; they consist in *tinning*, *backing*, *squaring*, *planing*, "*picking*," &c., and finally mounting on wood for printing.

Coppering Iron Cylinders.—The old method of coppering the iron rollers used in calico and paper printing was by means of a single cell and a number of porous pots arranged around the surface. The improved plan is much more rapid, and is incomparably cheaper. The dynamo-electric machine is usually employed to furnish the current required. Large vats of solution are used, and the anode plates are curved to correspond with the curvature of the cylinders. By these means from four to six pounds of copper can be deposited upon a cylinder in eight hours. The solution employed in the preparatory process is a cyanide one, described at p. 103. In this solution, as described, the cylinder is merely covered with copper. The main deposit is secured in a common sulphate solution. The vats should always be horizontal ones, and the cylinders should be rotated slowly.

DEPOSITION OF ART AND OTHER WORKS.—This section is devoted to special treatment of art work, or electrotypes where rounded and undercut surfaces are constantly met with, presenting greater difficulties than plain flat work, as treated above.

One of the most important points to be constantly observed in depositing work with uneven surfaces is the tendency of the deposit to become thickened upon points and edges. Thus, a rounded surface presented to a flat anode will not receive a regular deposit; the shell of copper will be thickest at the line nearest the anode, and will from this point graduate off to nothing. This is another way of simply saying that *all parts of the cathode face must be equi-distant from the anode face.*

The smaller the articles deposited upon the more true is this, because the effect of the current is not sufficiently diffused to include all irregularities of the surface.

All rounded exterior surfaces can be deposited upon regularly by the use of one or a pair of concave anodes. The anode plates in this case should be thin, and may be bent and curved to answer pretty closely to the outline of the cathode. When both sides of an object are to be deposited upon at once, it is better to employ two curved anode plates, so arranged as to allow free circulation of the liquid by agitation or otherwise. In some cases the nature of the exterior surface may necessitate the employment of several anode plates, all connected, of course, to the positive pole of the battery. The main object is to effect an equal distribution of anode surface over the object. A flat object to be coated upon both sides at once may be hung between two anode plates, or between the two sides of one plate bent to a U shape.

Outside Undercuttings.—When a surface is very irregular, and especially when it is undercut to any considerable extent, it presents points difficult to commence a deposit upon. In many instances these undercuttings are so deep as to prevent the effect of the anode from reaching them. In most cases, also, these are met with upon blackleaded work, which augments the difficulty. But by a little skill the deposit may be commenced at those very difficult points by at first keeping out the regular anode, and employing one composed of a twist or two of copper wire, or a small plate sufficiently large to enter the deepest cavities of the cathode. When only a few of these cavities appear, the miniature anode may be mounted upon the end of a stiff wire, so that it may be bent to the position required to *lead the deposit just where the operator requires it to fall.* In some cases the current will be found too strong, and apt to give a black deposit if the regular anode is removed; but in any case the larger anode should be kept back until the hollows have been deposited in. By selecting a stiff, stout copper wire, and making as many loops upon it as will answer to the chief hollows, it may be so bent and arranged in a few minutes as to lead the deposit regularly into the hollows. These supplementary anodes must in all cases be connected with the positive pole of the battery.

Or another plan may be adopted from the beginning; but it is not generally applicable or necessary except when the undercutting is beyond the reach of the blacklead brush. Each hollow may be made to conduct better than the general surface by means of precipitated nitrate of silver (p. 169), or other solution used with elastic moulds. Undercut surfaces are, however, frequently deposited upon without any of the devices here mentioned. It is well known that a high electro-motive force tends to *spread* a deposit over a refractory surface. In this way it is by no means impossible to drive a deposit over *clean* gutta-percha. Hence, by adding to the electro-motive force of the battery, and employing only a small anode, most of the ordinary depressions on a mould may be reached very shortly after the general surface has been coated. It is, however, of the greatest importance to secure strong metal upon hollows, because these require the most strength, being the prominent portions of the electrotype.

The solution in the hollows, if allowed to rest, is very apt to become *weak*. The same may take place when anodes are employed to surround a cathode: in all such cases the solution must be made to circulate, by gently stirring or by shifting the anodes and cathode frequently. In some cases also copper anodes, unless of electrotyped copper, are so impure that the dirt set free effects much mischief. Platinum foil and wire are extensively employed as anodes, where common copper would be inadmissible. Instances of these applications are given further on in this chapter.

Interior Work.—Deposits upon the interior surfaces of moulds present those difficulties which most try the skill and forethought of the electrotyper. They must be formed, as has been shown in the section devoted to *Preparation*, upon all kinds of surfaces, and upon all the usual moulding materials. The most important outlook is to secure a really good conducting surface, as strong in the hollows as upon the heights. The negative conducting system must be as perfect as possible, and should especially include branches to all the hollow parts, as recommended at p. 175. These systems should, as much as possible, be so arranged as to allow of an anode being hung in the mould. The shape of this anode, in the case of a bust, should to a certain degree *correspond with the interior outline of the mould.*

Anodes of platinum wire are frequently employed in this way, made up as a kind of frame to the general interior outline, but small enough to avoid risk of touching within the mould. These anodes are afterwards, if the deposit be of the shape to necessitate it, pulled out through a hole in the head of the bust, or from underneath. In most cases of bust work, however, including many natural objects, there is an opening at the base of the mould large enough to allow of the use of a cylinder of sheet copper as an anode. A constant stream of the solution should be caused to flow through all interior moulds where copper anodes are employed; this is necessary, because these anodes are constantly giving off dirt, which is apt to fall into hollow places and so prevent the formation of a strong deposit there. A stream of the solution issuing from the lower part of the mould will carry all the usual impurities with it to the bottom of the vat.

Air bubbles, which in all classes of work give great trouble to electrotypers, must be especially guarded against in the deposition of interior work. Gas must also be avoided by regulating the current. Dipping the mould, or wetting it within, with spirits of wine has been recommended, but it is probably best to carefully carry out the instructions given at p. 157, regarding thoroughly wetting every portion of the mould with water simply, before placing it in the solution. A camel-hair brush may also be employed when the hand can be placed in the mould.

Some of the largest electrotypes, as that of the Earl of Eglinton (13½ feet high), made by Messrs. Elkington, are deposited by the process mentioned at p. 173. By these means, although the original (plaster bust or model) is destroyed in the process, most of the difficulties are removed, and a convex anode, with a skilful distribution of leading wires, secures the formation of a rigid shell. By these means the shell is deposited in parts and afterwards soldered together. The great advantage of this method lies in the certainty with which the deposit may be led over the whole surface. Each section should be deposited to a given thickness, or the lower portions of a statue may be made thickest to give strength to the whole.

The deposition of copper as applicable to every kind of art work may be fully studied upon exterior rounded surfaces. As much as possible the primary conditions should resemble those applied in common flat work; that is, the copper must be led to the required points by an intelligently-arranged system of anode surface and negative leading wires. The anode and negative wires should act in conjunction in drawing the deposit into difficult hollows. *The deposit always first falls at the point where resistance to the current is weakest.* Following this rule the protruding portions of the mould need no special arrangements to draw the deposit towards them.

In Chapter VII. are given numerous particulars in the preparation of the work previous to placing it in the depositing vat. We are chiefly concerned here with the actual deposition of the copper, which is always comparatively easy to carry out when the work has been carefully prepared. The three chief points to observe are—to obtain good copper, to obtain it in the hollows first, or as soon as possible by a combination of negative conductors and anodes, and to prevent the deposition of dirt upon any portion of the mould.

The Cause of Slow Deposits.—Slow deposits are always caused by weak currents; but the weakness of the current may arise from a variety of causes. As a rule, the deposit upon a blackleaded surface is slow in forming, but this is due to the great resistance offered by the imperfect conductor. As soon as the surface is covered the speed of deposition is greatly increased if the current be of proper strength. Then it follows that if a good strength of current be passing a corresponding amount of copper should be secured. It will, of course, be understood that as long as the actual facing is being deposited the work will be slow unless the electro-motive force be increased. There is no economy in increasing the *current* during this stage of the process. When the word *current* is used here it signifies the *actual* current, not the current which *might* pass if the resistance and distance apart were reduced. Thus, the currents yielded by a battery when on short circuit and when depositing copper are very different in strength. Work of any kind always reduces the current, and it is the amount of electrical energy actually passing that we have to deal with. Hence the work or depositing rate may be taken to be proportionate to the actual current. A rise of temperature will increase the current by decreasing the resistance.

Dirty Anodes.—It may prove both interesting and instructive to give some particulars of the cause of the films observed on copper anodes. They are usually brown or black in colour, and appear on the dissolving surface in proportion to the amount of copper withdrawn. This dirt is a source of great trouble to the operator, because it not only necessitates frequent cleaning of the anode, but falls to the bottom of the vat, and when disturbed is apt to get upon or into the moulds.

If the plan recommended by the author—that of using only Daniell cells and employing their electrotype copper for anodes—were once tried, it would probably be always used, because the copper is quite free from the foreign matters spoken of as dirt.

A chemist on analyzing the dirt found it to consist of a great number of different substances, among which the percentage of tin was 33, of copper 9, antimony 9, arsenic 7, silver 4, sulphur 2, and nickel 2.

Cause of Nodules.—These are little lumps of copper which frequently appear on the back of an electrotype and retard the progress of the real deposit. They are caused chiefly by employing a current too small and an electro-motive force too high. The formation of these warty excrescences, however, greatly assists in the spreading of a deposit over a refractory substance; they exert a repulsive effect which undoubtedly assists to a considerable extent the driving of a deposit into hollows in the mould. In such cases the current must be small. (See p. 197.)

Redissolution of the Deposit.—This must be especially guarded against, as, besides retarding the progress of the work, it is apt to render it porous and spongy. It is chiefly caused by carelessly allowing the battery power to become too weak, when the counter force of the depositing-cell (p. 18) is allowed to come into action to reverse the direction of electrolysis and dissolve the cathode. The same may take place when the dynamo-electric machine is employed, by allowing the work to remain in the bath while the machine is idle. In this case, if an efficient safety circuit-break, such as that devised by the author (p. 84), is not fitted to the circuit, the polarity of the machine is very apt to become reversed, and the current reversed also on again starting the machine. The result is, of course, to dissolve the deposit, and probably destroy the mould. (See also p. 83.)

Dynamo-electric Working.—Most of the necessary directions for the management of dynamo-electric machines have already been given (p. 82, Chap. III.). The bulk of liquid should be large, and an extended system of anode and cathode rods should cross the vat. The deposits are obtained with full current much more quickly than by the battery current, but no rapid deposition can be done on very small work; this is the reason why dynamo-electric currents are not economical unless employed in large baths upon large electrotypes. The battery current is better adapted in many ways for work of moderate size, and although it cannot be quicker in action than the machine current, it is in small operations much cheaper and more easily handled by the operator.

Cost of the Process.—Machine work is very much cheaper than battery work, and the copper on large electrotypes deposited by machine is usually of better quality. The actual cost of the dynamo-electric current per pound of copper, including labour, is frequently less than threepence, but the general cost with small machines will be higher. The battery current, reckoning the zinc salts, &c., to be thrown away, cannot be much less, without labour, than sixpence per pound of copper, because the zinc costs about fourpence per pound and acid about three halfpence. As a rule, the battery is more expensive than this, even in skilful hands, because two pounds of zinc are frequently dissolved in depositing one of copper.

The process of depositing hard facings for electrotypes is described in the succeeding chapter.

CHAPTER IX.

Hard Facings for Electrotypes.

ELECTRO-deposits of iron are exceedingly hard and strongly adherent. When a copy from an engraved steel plate is thinly coated or faced with iron by means of electricity it is said to be "steel-faced," and the term does not appear to be inappropriate when it is stated that a steel-faced electrotype can be made to stand wear even better than the original steel engraving. Iron electrodeposition is, indeed, almost confined to the facing of electro-plates. When the steel face wears off the residue may be dissolved away by means of dilute sulphuric acid without injury to the real face, and the process repeated with all the original sharpness an indefinite number of times. The iron takes ink more readily than most surfaces, and cannot, like copper, be injured by printing in vermilion, the mercury of which combines with copper. The plates from which bank-notes and cheques are printed are in most cases iron-faced.

Nickel may be used for the same purpose, and has lately been tried by the author with success. It is hard, strongly adhesive, and is more easily deposited than iron; it possesses, indeed, all the good qualities of iron without its tendency to rust. The iron depositing solution is readily decomposed by absorbing oxygen from the air, and otherwise gives much trouble. Nickel solution, on the other hand, can be kept for years without spontaneous decomposition occurring. On account of these obvious advantages, directions for working a nickel solution are given at p. 114, and instructions for its use further on.

Preparation of the Copper-plate.—At p. 110 will be found directions for making up an iron solution, and for its preservation when made. When a copper copy of a steel engraving has been secured, as directed at p. 193, it is removed from the solution and well washed; a level wooden block of the same size as the plate is covered with an adherent layer of stearine or wax, and the warmed copper-plate pressed face downwards upon it. When well secured in this way, and the face is protected from possible injury, the edges are sawn off square with the circular saw; the back, covered as it is with variously-shaped excrescences of copper, must be partly filed, and afterwards, if possible, planed level; the plate must, in fact, be made of a uniform thickness throughout. It is afterwards removed and the edges bevelled, so that when finished the plate shall be similar to the original.

Before steel-facing, the surface of the plate is cleaned off carefully by means of turpentine, benzine, and finally hot caustic potash solution, when, after washing, it is ready for the depositing process. Care should be taken not to touch the face of the plate with the fingers, as at that point the deposit of iron is liable to be defective and strip in the printing. The plate may be suspended in the solution by means of two hooks of copper wire, upon which its lower edge may rest; or a copper wire may be soldered to the back. The former method is generally considered the better.

A battery current of one gallon Bunsen cell (p. 50) is frequently employed, but it is too weak. Two cells should be used, exposing in each a surface of zinc at least as large as the plate to be faced. It is usually convenient to first immerse a plate of copper to find at what distance the anode should be placed from the cathode. The anode should have a surface about five times larger than the plate to be coated. When immersed for a few minutes, and a whitish coating is observed to spread over the surface, remove, wash, and rub with a brush; remove again and wash after a few minutes. Treat as before, and when the iron has spread well into all the lines it may be considered sufficiently deep. Wash the plate in hot water very carefully when finally removed, and if not intended for immediate use, dry slowly and coat the surface with bees'-wax by the aid of heat. The deposit must not, of course, be allowed to go so far as to affect to any considerable extent the fine lines of the engraving, but it must be allowed to cover the whole surface of the plate. When a strong current is used the deposit is more apt to contain gas, but this can be avoided by more frequent removal and brushing. The fingers should not be allowed to touch the face of the plate, except under the solution.

A very large anode must also be used, otherwise the solution will get weak and acid. In this process the usual practice of providing an anode of a size equal to the cathode must be departed from. The iron composing the anode should be as fine as possible. Charcoal iron is generally employed with the best results. Gas is very apt to come off in the operation, but its presence, as the deposit is so thin, may be overlooked. The plate may with advantage be gently swung from side to side during the process.

Nickel-Facing.—This process is much more easily carried out than that of iron-facing. The nickel solution required is described at p. 114. It should be in good order, neither distinctly acid nor alkaline, but if anything the alkaline tendency should predominate. It is not even necessary in depositing small quantities of nickel, such as those required in facing plates, to employ a nickel anode, but it is always desirable and wise to do so. Occasionally a platinum foil anode can be made to answer, but the state of the solution must thereafter be brought into working condition by the addition of the abstracted nickel, and also sulphate of ammonia to represent the alkaline constituent necessary to balance the acid.

A current from one Bunsen cell will usually prove sufficient. Great care should be taken to remove every trace of wax from the plate to be faced by means of benzine, and afterwards to wash well in hot caustic potash solution; it is even advisable to boil the plate in the solution for fifteen minutes, and afterwards to wash well in water. The fingers should on no account be allowed to touch the face of the plate, otherwise the deposit may fail to adhere to the parts. The anode should have a surface a little larger than the plate. When the latter is suspended in the solution, it will prove advantageous to go over its surface with a long-handled soft brush, to dispel any films of air or bubbles of gas. When the first trace of a deposit appears, the brushing may be repeated, and in a few minutes the plate may be removed, washed, and then replaced. At this stage the process is the same as that given for iron-faced plates. The deposit will be sufficiently thick when it has entirely covered the plate.

A strong current offers no advantages; it is liable to produce a porous deposit, even in the extremely thin coating required; it is apt also to fill the hollows with gas and prevent the deposit from spreading easily between the lines. The object to be attained is a deposit accompanied with little or no gas. Rapid deposits are apt to be softer than slow deposits in the copper solution, and this is not less true when applied to nickel. Deposits formed slowly are always more highly crystalline than those formed quickly, and are therefore harder and more brittle. There is little or no tendency to strip, even when the plate has been prepared carelessly.

Brass-Facing.—Electro-deposited brass may be made very hard, and thus forms a good facing especially for bookbinders' tools.

The process is somewhat difficult, but there is the advantage of being able at will to obtain hard and soft brass according to the proportion of zinc contained in the deposit. The solution required has been described at p. 115.

The articles are prepared as for iron or nickel facing. The anode used should be of a hard yellow brass. One cell of the Bunsen type will deposit the alloy, but two are generally used to hasten the operation. If the brass should be red it will prove soft, and contain too great a percentage of copper. A solution with this defect may be corrected by the use of a zinc anode until the brass exhibits a rather pale colour. When the zinc constituent of the alloy is in excess it adds, up to a certain point, to the hardness of the deposit. The process of depositing should not be hastened, because too great a proportion of copper is then thrown down, and the zinc itself tends to add to the softness. What is really required in a brass-facing is great hardness and perfect adhesion between the real surface and the artificial face.

The author has successfully tried a method ot giving to ordinary electrotypes a very hard face by means of zinc. The first deposit thrown upon the mould, forming the surface of the electrotype, is precipitated by the aid of increased battery power, and in a solution of which zinc forms a part. This deposit secured, the electrotype is removed and completed in the ordinary copper bath. The result is a facing much harder and more durable than copper itself, with the additional advantage that it does not, like pure copper, readily give way when printing vermilion.

A solution suitable for this work may be made in a separate vessel by simply working a copper bath with a brass anode and a current from about three Bunsen cells in series, until a good hard deposit can be secured upon a copper plate or a blackleaded surface. The ordinary copper bath should not be employed for the purpose. Gas is generally given off, especially at the cathode, the surface of which should be frequently cleaned by means of a soft brush. When the deposit becomes too pale employ a copper anode for a time. (See p. 187.)

CHAPTER X.

Final Preparation of the Work.

After an electrotype is removed from the depositing solution, it is "finished;" that is, trimmed, backed, and mounted, if it belong to the printing class, or trimmed and joined to its corresponding section if it belong to the art electrotype order. The finishing of printing electrotypes is by far of the greater importance, and requires the exercise of the best skill; it generally is, and always should be, a distinct operation, performed by special workmen trained to it. In most cases the finishing and correcting of printing electrotypes demands the attention of more than one special workman, as will be judged from the condensed description of the whole process given herewith.

Finishing of Printing Surfaces.—When the electrotype is judged to be thick and rigid enough ($\frac{1}{32}$nd of an inch for backed work), the mould is removed and well washed. It is laid electrotype upwards and hot water poured upon the latter; this has the effect of softening the wax and freeing the shell. When any fragments of the shell hang over the edges of the mould they should be clipped off previous to heating. A minute examination should be made at this stage of the face of the shell in order to find any defects that may exist, especially pinholes.

Tinning.—The backing process is preceded by that of *tinning*, in which floating or tinning-pans and the backing metal bath mentioned at p. 137 are employed. The tinning-tray is first floated upon the molten metal until quite hot; the electrotype is laid upon it, face downwards, and a quantity of hydrochloric acid, in which zinc has been dissolved to saturation, thoroughly brushed over its back. This solution of zinc is usually called tinning or soldering fluid, and should be kept in a bottle for use. The tinning metal is usually a mixture of lead and tin, prepared by melting together equal parts of tin and lead, and either running it into thin sheets, to be cut into strips for use, or pouring it into water to obtain *grain solder*. A quantity of this solder is sprinkled over the back of the shell, and caused to spread, when melted, by the aid of a stick of solder or a stiff brush wetted with the soldering fluid. The tin must in all cases spread all over the electrotype back, and must also be caused to "take" to the surface, as mercury is observed to amalgamate with zinc.

Precautions.—In the case of there being pinholes through the electrotype, the soldering fluid must be used more sparingly, because it is apt to find its way through the defects and attract the solder to the front, spoiling the printing surface. If the soldering fluid should exhibit any tendency to turn black upon the surface of the shell, a little water may be added to it, also a fragment of an alkali, as chloride of ammonium. Care should be taken to keep the heat as *low* as possible, consistent with free diffusion of the solder. If the shell should exhibit a tendency to curl up at the edges, weights of any kind may be employed to keep them flat until backed and cool.

Backing.—When properly tinned, iron bars may be so placed, if necessary, as to confine the metal to be poured on to the surface of the shell. The backing metal is ladled out of the melting-pot and poured upon the shell, commencing at one corner, until a moderate thickness is attained, so that enough may be left to plane down to gauge. Both tray and shell are removed together and allowed to cool.

Squaring.—The superfluous width of shell and back may now be reduced by means of the circular saw to within one-fourth inch of the engraving or type, care being taken to cut square and straight to gauge.

Levelling.—Shells are seldom sufficiently rigid to prevent slight twisting or depression of the printing surface from appearing. When backed and cool they are, therefore, examined by means of a straight-edge and callipers, and any depressions from the general surface carefully marked on the *back*. After this examination, the printing surface is placed upon a level and smooth iron block and the depressions corrected from the back by means of a smooth and round-faced hammer; the blows should not be harder than will actually serve the purpose. When the face is "home" to the level, which is indicated by the solidity of the sound, it should be again examined from the other surface by means of the straight-edge. Sometimes the plate is further "planed" by the application of a printer's planing-block, of small size.

Roughing.—This is the next operation; it consists in cutting away, by means of a "roughing lathe," all backing metal not parallel with the printing surface of the electrotype. In many cases this process is made to complete the plate previous to mounting. The lathe has already been described (p. 138). A single layer of thin paper should be smoothly glued over the surface of the revolving face-plate to prevent injury to the printing surface. The electrotype should be secured by means of the chuck-jaws as nearly as possible in the centre of the face-plate, and revolved at a high speed. The cutting-tool or knife should be kept moistened with water. When the plate has been faced it is removed, and should be finished in the planer to the standard gauge.

In both the roughing and planing operations care must be taken that the electrotype shall lie quite flat to the face-plate and the planing-bed.

In the former case the chuck-jaws must be set so as to obviate twisting or bending the plate, or otherwise disturbing its accurate flat surface. It is always well to have at hand a small printing-press, in which a preliminary "pull" can be obtained, to prove the flatness of the plate.

Bevelling.—It is now usual to bevel off the edges of the electrotype in the bevelling machine, mentioned at p. 139; but in some cases it is done by hand with a sharp file. A bevelling-plane is, however, much better adapted to the work, but care must be taken in either case to avoid working too near to the edge of the engraving or type. When the electrotype is to be mounted upon wood, the bevelling may be done by hand and file, but otherwise it is not only necessary to square and bevel off very accurately, but to make every plate of the same work correspond in size with any other plate of the set, otherwise much confusion is likely to result in arranging them for the printing process.

Correcting and Routing.—In cases where the original plate has been perfect and care taken in producing the electrotype, there should be little need for the troublesome process variously known as correcting, picking, &c. But in general practice there is constant work for the corrector, in picking out accidental points of backing metal, clearing lines, repairing damaged letters, and so on. In addition to this each electrotype should be "chipped" or "routed"—an operation which means the deepening of the central portions known as the "whites," so that they may not black in printing.

The picking process must be conducted with a steady and skilful hand by the aid of a few engravers' tools. In repairing battered letters it is usual to either "knock up" or otherwise raise the surface from the back, and so obtain matter to work upon at the face, or to drill out the letter, square the hole, and insert a new one by the aid of solder and the blowpipe. When new letters are inserted, or new portions of a woodcut, care must be taken to insure that the new portion shall not be higher or lower than the old face. This class of work is secured from behind by wetting it with soldering fluid and soldering by the aid of a blowpipe and a few grains of tinning composition. All points of tin or backing metal projecting through the face, owing to holes in the electrotype, must be carefully removed with suitable tools.

The chipping or routing operation is done on a small scale by means of sharp chisels with rounded faces and a hammer, but in the larger establishments a machine with a rapidly-revolving cutter is provided, which speedily cuts away and deepens the "whites." It is usually necessary in this operation to cut away portions of the shell and some thin portion of the backing metal.

Additions to the Electrotype.—In some cases the necessity arises for an addition to the plate, upon which the design of the engraving may be continued; or sometimes two electrotypes of engravings may be combined to act as one. The greatest care is necessary in this work to insure that the joined edges shall be straight and true, otherwise the join will exhibit as a white line in the printing. The blowpipe and soldering bolt are generally employed in this work.

Mounting.—Electrotypes of woodcuts are usually mounted upon mahogany blocks (p. 139), which are afterwards accurately planed to type gauge. The block should be of the same size as the plate; it should not in any case be smaller; its surface must be perfectly level, otherwise the plate will be twisted, and will not print all over its surface.

In most cases holes should be drilled in the plate for the pins, because driving them through the metal frequently tends to twist the surrounding portions. French pins with small heads are usually employed. They should be placed around the edges first; a pin or two should be driven well home in the whites. The holes should be countersunk, so that the pinheads may not protrude. A steel punch and hammer must be used. All the pins should not be driven home at once as they are entered, but afterwards, as the plate tends to lie on the block. Flatness and freedom from warping is the object of this. The electrotypes, after being mounted, are always gauged by passing them under a standard gauge mounted on a level plate. Each block should be planed carefully to the gauge, or if anything rather thinner, as they can afterwards be corrected for height by underlaying with paper.

Storing Electrotypes.—Plates mounted upon wood should always be kept in a dry place, because the mahogany is apt to absorb moisture and warp or swell. As a rule, electrotypes of this class should be stored in shallow drawers, only slightly deeper than type-high. In packing, the printing faces must always be protected by one or two layers of soft paper, and care should be taken to so arrange the blocks as to be free from shaking or possible movement. The top and bottom faces of the sets of plates should always be turned towards each other for the sake of protection.

Rotary Electrotyped Plates.—The flat electrotypes may be arranged in the form of cylinders when required to be worked upon rotating printing machines. Several methods are in use. The shell should first be corrected to the flat form and then tinned on the back. In curving it a cylinder of the required size may be used, and an outer convex casing provided, between which and the electrotype back a layer of backing metal may be poured. The final corrections and planing may then be proceeded with, similar to the methods adopted in finishing common stereotype plates. By employing moulding cases of a convex pattern, filled to a uniform height with the wax composition, convex printing surfaces may be deposited upon moulds from curved stereo-plates.

FINISHING ART WORK.—*Medallions* may be backed with pitch, plaster of Paris, sealing-wax, or backing metal. In the latter case, the shell is placed on a wire-gauze plate, or on a bed of asbestos, and heat applied *gently* from underneath; the back is wetted with soldering fluid and tinned exactly as described (p. 213) for printing shells. The backing metal may be poured on or melted in position by means of a blowpipe. This backing is, of course, applicable to all flat art work of the medallion kind.

When two electrotypes of a medallion have to be joined together to resemble the original, they must be trimmed with the file and shears, and levelled to the required thickness. Heat may then be applied and the backs tinned; a layer of backing metal may also, if required, be melted upon each. When the two sides are properly adjusted to each other, so that the faces may lie correctly, additional heat, gently applied to avoid oxidation, will melt them in position, and the edges may be finished off with the file. In some cases a slight coating of copper around the edge may be applied to cover over the join and give the reproduction a finished appearance. A number of recipes for *colouring* and *bronzing* the finished electrotypes of all kinds have been given at p. 184.

Busts.—When a bust has been electrotyped in two parts the shells are trimmed with shears and file until their separating edges agree. The edges may then be wetted with soldering fluid and tinned with an ordinary tinman's bolt. When the edges are placed together, the flame of a lamp directed upon the seam by a common blowpipe can be made to heat the shells sufficiently to melt the tinning and secure the joint. When finally rubbed over with the file the joint may be bronzed.

In cases where the hand may be placed within the joined-up shells the uniting process is simplified by employing the soldering-iron. In many cases the shells are too weak to stand fair usage, and they must be backed by tinning and pouring on metal, as described for printing plates (p. 214). The backing in this case should be allowed to run into the hollows, because these are usually the thinnest portions of the shell. These hollows are often so weak by reason of defective anode arrangements that a slight touch will dimple them, and they are frequently pierced with holes, due to air bubbles or gas. Through these holes the tinning and backing metal are apt to run, but the protuberance can easily be chipped off and the spots bronzed or covered with bronze powder dusted upon gold size.

Shells that are required to support any considerable weight must be more rigid than common shells. The additional strength may be always applied by means of backing metal. When large shells are heated to be tinned and backed, various substances may be spread over their surfaces, so that they may be floated direct upon the molten backing metal. They may be blackleaded all over or covered with other substances to prevent the surface from "taking" the metal upon the wrong side. Smaller shells can be readily heated by means of a well-distributed gas flame through a bed of asbestos.

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